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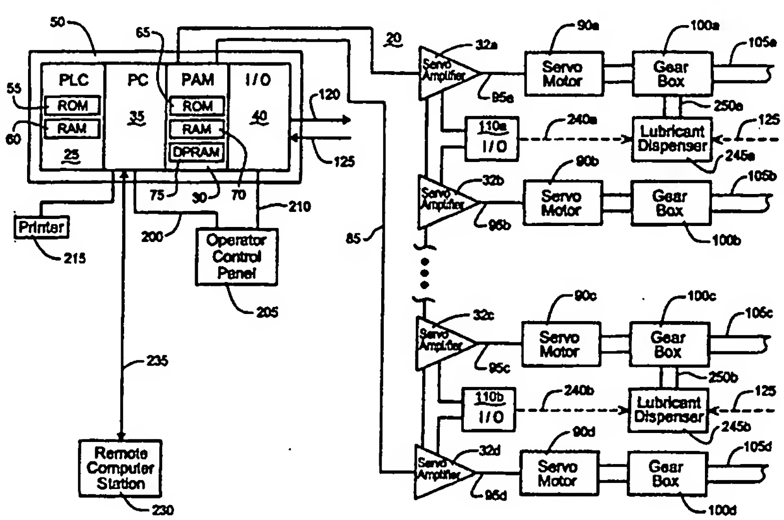

(57) Abstract

A servomotor driven machine under control of a control system is disclosed that incorporates a diagnostic system for early detection of the need for service thereby allowing for preventive maintenance to avert machine failure. The control system includes a servomotor (90) that drives a movable component of an apparatus. A controller (20) is provided for directing the movements of the servomotor (90) in accordance with a predetermined motion profile. The controller (20) monitors torque load on the servomotor (90) within a predetermined time frame and compares the monitored torque load with one or more predetermined service torque values to determine whether a service condition exists that requires maintenance. A status indicator responsive to the detection of a service condition by the controller (20) is employed to provide an indication of the service condition to, for example, an alphanumeric or graphic display (205) or printer (215), a central computerized maintenance scheduling system (230), and/or an automatic maintenance system.

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DIAGNOSTIC SYSTEM FOR A SERVOMOTOR DRIVEN APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. Serial No. 08/385,414 filed September 28, 1994, which is a continuation-in-part of U.S. Serial No. 08/190,546, filed February 2, 1994.

TECHNICAL FIELD

The present invention relates to a diagnostic system for a servomotor driven apparatus. More particularly, the present invention relates to a control system for a packaging machine that includes a diagnostic system to determine whether service of the apparatus is needed and to provide an indication of that need to, for example, a user of the apparatus.

BACKGROUND

Packaging machines are known that integrate the various components necessary to fill and seal a container into a single machine unit. This packaging process, generally stated, includes feeding carton blanks into the machine, sealing the bottom of the cartons, filling the cartons with the desired contents, sealing the tops of the cartons, and then off loading the filled cartons for shipping. The motion and I/O control of the packaging machine may be undertaken by an electronic control system.

Trends within the field of packaging machines point toward increasingly high capacity machines intended for rapid, continuous filling and sealing of a

very large number of identical or similar packaging containers, e.g., containers of the type intended for liquid contents such as milk, juice, and the like. One such machine is disclosed in U.S.S.N. 08/190,546, filed February 2, 1994, which is hereby incorporated by reference and the enhancements thereto that are disclosed in U.S.S.N. 08/354,313, filed September 28, 1994, which is likewise incorporated by reference. The machines disclosed in these applications include a plurality of processing stations, each station implementing one or more processes to form, fill, and seal the containers. Each of the processing stations may be driven, either directly or indirectly, by one or more servomotors that drive the various components of each of the processing stations under the control of a control system.

For a servo controlled packaging machine to perform properly, the machine's repeatability of motion should be within design specifications. In most cases, the movement of the various moving components of the machine along all motion axes must be controlled within very small tolerances. For example, within a packaging machine of the type disclosed in the aforementioned applications, the moving component of each servomotor driven apparatus may be required to be within $\pm$ 0.5 mm of a designated position throughout its movement cycle. Over time, the moving components and the associated drive mechanisms of the machine may experience substantial wear which prevents the motion of the components of the machine from meeting design specifications. Ultimately, catastrophic failure of the machine may result without any prior notice of the impending failure and/or without any prior remedial action being

taken to avert the failure. The machine may thus require costly repairs which prevent use of the machine for an extended period of time.

To limit the risk of catastrophic failures of the machine, most machine users implement routine maintenance at scheduled intervals. Such routine maintenance may be scheduled, for example, based on the number of hours that the machine is operated, a fixed period independent of machine operation, etc. A single maintenance schedule, however, is not always suitable and may result in the performance of unneeded maintenance with respect to some machines or machine parts and a failure to adequately maintain others.

SUMMARY OF THE INVENTION

A servomotor driven machine under control of a control system is disclosed that incorporates a diagnostic system for early detection of the need for service thereby allowing for preventive maintenance to avert machine failure. In accordance with one embodiment of the present invention, the control system includes a servomotor that drives a movable component of an apparatus. A controller is provided for directing the movement of the servomotor in accordance with a predetermined motion profile. The predetermined motion profile defines the motion characteristics of the movable component as the movable component moves from a start position to an end position within a predetermined time frame. The controller monitors torque load on the servomotor within the predetermined time frame and compares the monitored torque load with one or more predetermined service torque values to determine whether a service condition exists that requires maintenance. A status indicator responsive to the detection of a service condition by the controller is employed to provide an indication of the service condition to, for example, an alphanumeric or graphic display, a computerized maintenance scheduling system, and/or an automatic maintenance system.

In accordance with other aspects of the present invention, the controller monitors the torque load on the servomotor at a plurality of times during the predetermined time frame and compares the monitored torque loads with predetermined maximum and/or minimum service torque load values for the respective time. The torque load is thereby monitored at various times during the execution of the motion profile and is compared to one or more expected torque

load values to provide a more accurate indication of whether a service condition exists.

In accordance with one embodiment of the present invention, a packaging machine is provided which includes a plurality of packaging stations, each executing one or more processes to fill and seal a plurality of packages. A conveyor transports the plurality of packages between the plurality of packaging stations. A servomotor is connected to drive at least one movable component of at least one of the plurality of packaging stations. The at least one movable component is driven by the servomotor from a start position to an end position. A controller is employed for directing the movement of the servomotor in accordance with a predetermined motion profile, the predetermined motion profile defining motion characteristics of the movable component as the movable component moves from the start position to the end position within a predetermined time frame. The controller monitors torque loads on the servomotor and compares the measured torque loads to predetermined service torque values to determine whether a service condition exists. A status indicator is responsive to detection of a service condition by the controller to provide an indication of the service condition.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic block diagram illustrating one embodiment of a control system for controlling the operation of the movable components of a machine.

FIG. 2 is an exemplary graph of torque-vs.-time for a servomotor.

FIG. 3 is a flow diagram illustrating one manner in which the system of FIG. 1 may be used to detect and act on the occurrence of a service condition.

FIGs. 4A and 4B are more detailed flow diagrams illustrating one manner of sensing and acting on a service condition using the system of FIG. 1 wherein the system comprises both a PLC and a PAM.

FIGs. 5 and 6 illustrate one manner of detecting and acting on a service condition based on the backlash that is detected by the system of FIG. 1.

FIGs. 7 and 8 are schematic illustrations of a packaging machine that utilizes the system of FIG. 1, where in the machine comprises a plurality of processing stations that each include one or more servo driven mechanisms.

FIGs. 9-35 are exemplary motion profiles that may be executed by the mechanisms of the various package processing stations of FIGs. 7 and 8 under control of the control system of FIG. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 is a schematic block diagram illustrating one embodiment of a control system for controlling the operation of a plurality of movable components of a machine, such as a packaging machine of the type described in the foregoing patent applications. The illustrated control system includes a controller, shown generally at 20. The controller 20 includes a programmable logic controller ("PLC") 25 and/or a programmable axis manager ("PAM") 30, depending on the demands placed on the control system, as well as servo amplifiers 32. A single PLC without a corresponding PAM, for example, may be utilized in instances in which the control system 20 must respond and control a large number of I/O signals while, at the same time, control motion along a minimal number of axes. A single PAM, however, may be utilized in instances where it is necessary to control a large number of motion axes, but in which the system need not control and respond to a large number of I/O signals. The illustrated controller 20 uses both a PAM 30 and a PLC 25, and, as such, may respond to and control a large number of I/O signals as well as effect motion control of a large number of motion axes. Controller 20 may also include an industrial PC 35 and an I/O interface unit 40. The PLC 25, PC 35, PAM 30, and I/O interface unit 40 may all be disposed in a bus rack 50 for communication with one another. Communication between the PLC 25 and the PAM 30 may ensue at a high data rate using, for example, the communications programs described in the '414 patent application. The bus rack 50, may be a VME bus, a SIMATIC S5 bus, or any other bus that is capable of supporting multiple processors.

As illustrated, the PLC 25 includes a ROM 55 and a RAM 60. The ROM 55 includes, for example, the software that is required to program and run the PLC 25 and, for example, may include E^2 PROM for storing the ladder logic programming and motion profiles associated with the components that are to be driven by the control system. The PAM 30 includes a ROM 65, a RAM 70, and a DPROM 75. The ROM 65 includes the programs necessary to operate and program the PAM 30 and, for example, may include E^2 PROM for storing the user program, including motion profiles associated with the various components that are to be driven by the control system.

The PAM 30 is connected for communication with a plurality of servo amplifiers 32 along one or more lines 85 which may constitute, for example, an optical ring network. The servo amplifiers 32, in turn, are each connected for control of a respective servomotor 90 along lines 95. The servomotors 90 are connected to drive the various movable components of a machine, either directly, or indirectly through intermediate drive mechanisms 100, such as belts or gearboxes. In the illustrated embodiment, the intermediate drive mechanisms 100 connect the servomotors 90 to respective drive shafts 105 that drive the movable components of the apparatus, for example, through further belts or the like.

By way of example, the servo amplifiers 32 may each be a Model ST-1 servomotor amplifier and the PAM 30 may be a programmable axes manager, both of which are manufactured and available from Socapel. Similarly, by way of example, the PLC 25 may be a Model 9070 programmable logic controller that is available from GE Fanuc.

In the case where one or more Model ST-1s are used to implement the system, the servo amplifiers 32 may be used to sense and propagate I/O signals through, for example, I/O interface circuits 110. The status of sensor inputs as well as the control of actuating outputs to and from the I/0 circuit 110 are communicated along the optical ring network to PAM 30.

The PLC 25 is in communication with the I/O interface unit 40. The I/O interface unit 40 receives and sends I/O sensor and control signals along lines 120 and 125.

The controller 20 directs the servo-amplifiers 32 to cause the servomotors 90 to drive the moving components of an apparatus, such as a packaging machine, in accordance with predetermined motion profiles that are stored as digital data in the electronic memory of the controller 20. The predetermined motion profiles define the motion characteristics of the movable components as they are each driven from a respective start position to a respective end position. The movement of each of the movable components from the respective start position to the respective end position takes place during a predetermined time frame that is defined by the stored motion profile for the particular movable component.

During execution of the stored motion profiles by the control system, the controller 20 monitors the actual torque on each of the servomotors 90. The actual torque, for example, may be sensed by monitoring the current drawn by each of the servomotors 90 and converting the sensed current to digital data that may be used by the controller 20. In the exemplary system shown in FIG. 1, the actual torque value (ATV) on each of the servomotors 90 is sensed by the servo

amplifiers 32 and transferred as a digital variable to the PAM 30 along lines 85. Upon receipt by the PAM 30, the actual torque value ATV may be communicated to the PLC 25 as a system variable, for example, in accordance with the communication system disclosed in the foregoing '414 application.

FIG. 2 is an exemplary graph illustrating torque-versus-time for a single servomotor 90a driving a movable component of an apparatus. It will be recognized that the time axis may alternatively represent position of the servomotor 90a.

In the illustrated graph, the controller 20 begins to direct the servo amplifier 32a and servomotor 90a to execute the stored motion profile associated with the moving component driven by servomotor 90a at time t0 and completes execution of the motion profile at time t6. Line 140 represents the torque that is expected on servomotor 90a over the time frame t0-t6 of the motion profile. Dashed lines 145 and 150 represent predetermined maximum service torque values and predetermined minimum service torque values, respectively, over the time frame delimited by t0 and t6.

The predetermined maximum and minimum service torque values 145 and 150 are used by the controller 20 as a basis for determining whether the mechanical components associated with servomotor 90a (i.e., the servomotor 90a, the movable component, the intermediate drive mechanism 100a, etc.) are in need of service. The actual torque values on the servomotor 90a will exceed the predetermined maximum service torque values of line 145 if, for example, the components associated with the servomotor 90a are in need of lubrication or are otherwise difficult to move. As a result, if the actual torque value ATV

measured by the controller 20 exceeds the predetermined maximum service torque value for a particular time, for example, PMXTV1 at t1, then one or more of the components associated with the servomotor 90a requires service, for example, lubrication, replacement, etc. Similarly, the actual torque values on the servomotor 90a will be below the predetermined minimum service torque values of line 150 if, for example, the components associated with the servomotor 90a are worn and are thus slipping. Consequently, if the actual torque value ATV measured by the controller 20 falls below the predetermined minimum service torque value for a particular time, for example, PMNTV1 at t1, then one or more of the components associated with the servomotor 90a requires service, for example, replacement of worn parts. If at any time the actual torque value exceeds a predetermined maximum emergency stop torque value, designated here as ESTV, the controller 20 executes an emergency shut down procedure to stop the servomotor 90a and, in most instances, all other servomotors of the system. In stopping the servomotors, a delayed braking apparatus such as the one disclosed in U.S.S.N. 08/315,407, filed September 28, 1994, may be utilized.

FIG. 3 illustrates one manner in which the controller 20 may operate to detect a service condition and then act in response to the sensed service condition. At predetermined times (or positions), t1 through t5, the controller 20 detects that there is a need to check the actual torque load on the servomotor 90a at step 160. This need may be prompted by an interrupt or the like. At step 165, the controller 20 proceeds to get the actual torque value on the servomotor 90a. The controller 20 then compares the actual torque value that it obtains with predetermined maximum and minimum service torque values associated with the

particular time (or position) at steps 170 and 175. For example, the controller 20 compares the actual torque value measured at time t2 to PMXTV2 and PMNTV2 (FIG. 2). The PMXTV2 and PMNTV2 values may be stored, for example, in a look-up table in controller memory. If the actual torque value ATV is between PMXTV2 and PMNTV2, then there is no need for service and the controller 20 continues normal processing at step 180. If the actual torque value is outside the limits defined by PMXTV2 and PMNTV2, then a service condition exists and the controller 20 provides an indication of the need for service at step 185 before continuing with its normal operation at step 180.

It will be recognized that some degree of hysteresis may be desirable before the controller 20 declares a service condition. For example, the controller 20 may be programmed to detect several ATVs outside of the range delimited by lines 145 and 150 before declaring a service condition. The detection of ATVs outside the delimited range may take place in a single execution of the respective motion profile or in multiple executions of the motion profile.

The indication that a service condition exists can take on many forms as will be explained in connection with FIG. 1. For example, the controller 20 may send the necessary signals along lines 200 to provide a visual indication of a need for service on the operator control panel 205. The visual indication may be presented, for example, in the form of a service lamp which lights in response to the controller 20 when the controller 20 detects a service condition. Such a lamp may alternatively operate in response to one or more output signals along lines 210 from the I/O circuit 40. The visual indication may also take the form of a graphic or alphanumeric message on a display (LCD, LED, CRT, etc.) on

the operator control panel 205 or at some other location. The indication of service provided by the controller 20 may also take the form of a printed service report that is printed by a printer 215 under the control of the controller 20. In the illustrated embodiment, report printing by printer 215 and control of the operator control panel 20 are executed by the PC 35. In each instance, the service indication may identify the need for service as well as which components require service.

In accordance with one embodiment of the presently disclosed system, the controller 20 may communicate the need for service to a computer station 230 that is remotely located from the apparatus. Communication between the controller 20 and remote computer station 230 takes place along lines 235 that, for example, may be a telephone line for modem communications, a dedicated optical communication line, or the like. The remote computer station 230 may communicate with a plurality of control systems that are each associated with a respective apparatus thereby providing a site for central monitoring and scheduling of service. The remote computer station 230 may provide printed reports of a need for service as well as identify, either graphically or in alphanumeric format, the particular components in need of service.

In accordance with a still further embodiment of the presently disclosed system, the controller 20 may provide signals along either lines 125 or lines 240 to a lubricant dispenser 245 upon detection of a service condition. In the illustrated embodiment, the lubricant dispenser 245a is connected to supply lubricant to gear box 110a associated with servomotor 90a. Lubricant is dispensed through fluid line 250a to the gear box 100a under control of the

controller 20 when, for example, the actual torque value measured by the controller 20 on servomotor 90a is equal to or exceeds one or more predetermined maximum service torque values. The signals to actuate the lubricant dispenser 245a may be supplied from the I/O circuit 40 along one or more of lines 125 when the PLC 25 detects a service condition. Alternatively, the signals to actuate lubricant dispenser 245a may be supplied along one or more lines 240a from I/O module 110a after the PLC 25 detects a need for service and communicates the need for service to the PAM 30 for further transmission to servo amplifier 32a and therefrom to I/O module 110a.

FIGs. 4A and 4B illustrate one manner in which the controller 20 may detect and respond to the need for service in instances in which the controller 20 is designed to comprise both a PLC 25 and a PAM 30. The communications between the PLC 25 and the PAM 30 may take place in accordance with the teachings of the foregoing '414 application.

Upon determining that the time (or position) for monitoring the actual torque load on the servomotor has been reached at step 300, the PLC 25 sends a request to the PAM 30 at step 305 requesting the PAM 30 to ascertain the actual torque value (ATV) and communicate the value to the PLC 25. When the PAM 30 receives the ATV request from the PLC 25 at step 310, the PAM 30 proceeds at step 315 to obtain the ATV from the servo amplifier 320 along, for example, communication lines 85 (FIG. 1). Once the ATV is received from the servo amplifier 32a, it is communicated to the PLC 25 through, for example, the DRAM 75 at step 320 and the PAM 30 continues its normal processing operations at step 325.

While the PAM 30 is processing the request for the ATV, the PLC 25 may execute a loop and wait at step 330 until the ATV is received or it may execute other tasks until the ATV is received. Once the ATV is received, the PLC 25 fetches the predetermined maximum torque value PMXTV for the particular time (or position) at step 340. The value is fetched, for example, from a look-up table in the PLC's memory. The value is then compared at step 345 to the ATV. If the ATV is less than the PMXTV, the PLC 25 fetches the predetermined minimum torque value PMNTV for the particular time (or position) at step 350 and compares the PMNTV to the ATV at step 355. If the ATV is greater than the PMNTV, then a service condition does not exist and the PLC 25 continues with its normal processing at step 360. If, however, the ATV is equal to or greater than the PMXTV or is less than or equal to the PMNTV, then a service condition exists and the PLC 25 provides a signal indicating the need for service at step 365. As noted above, the response to the signal can take on many forms.

Backlash in the servomotors 90 as well as the indirect drive mechanisms 100a, 105a, and any further components connecting the servomotors 90 to the movable components of the apparatus can also be used to provide an indication of the need for service of either the servomotors 90 or any intermediate component. FIGs. 5 and 6 illustrate one manner in which the controller 20 may monitor the backlash associated with either the servomotors 90 or the indirect drive mechanisms.

In the embodiment illustrated in FIGs. 5 and 6, servomotor 90a is driven from position P1 to position P2 and then from position P2 to position P1. The

position of the servomotor is detected through use of a resolver when, for example, an ST1 servo amplifier and associated servomotor are employed. The time, t1, that it takes for the servomotor 90a to go from position P1 to position P2 is compared with the amount of time, t2, that it takes the servomotor to go from position P2 to position P1. Ideally the servomotor 90a will not exhibit backlash and the times t2 and t1 will be equal. However, most servomotors will experience some degree of backlash and times t1 and t2 will not be equal. The difference between t1 and t2 is therefore compared to a predetermined time error value $t_{service}$ to determine whether the backlash exceeds a predetermined limit. If the difference exceeds this predetermined error value t_{error}, a service condition exists. If the difference does not exceed this error, then there is no need for service as per the backlash measurement.

The foregoing backlash detection system may also be used to determine whether the backlash of the indirect drive mechanisms 100, 105, and other components connecting the servomotors 90 to the respective movable components exceeds selected limits and thus requires service. In such instances, sensors are utilized to detect the position of the movable component at positions P1 and P2 as opposed to the resolvers used to measure the position of the servomotor 90. Hall effect sensors, infrared sensors, mechanical limit switches, etc., may be used for this purpose.

FIG. 6 provides a more detailed illustration of how the controller 20 may monitor and respond to backlash of either the servomotor 90 or the indirect drive mechanisms. As shown, the servomotor (or movable component) is first initialized to position P1 at step 400. The controller 20 then stores the time (for

example, the time of a real time clock disposed in the controller 20) as t_{init} (see also FIG. 5) and directs the servomotor 90a to go to position P2 (or to drive the movable component to position P2) at step 410. At step 415, the controller 20 determines when the servomotor 90a (or movable component) reaches position P2. When the servomotor 90a (or movable component) reaches position P2, the controller 20 stores the time as t_{final1} (FIG. 5) and directs the servomotor to return to position P1 (or directs the servomotor to drive the movable component to position P1) at step 420. The controller 20 then determines at step 425 when the servomotor (or movable component) reaches position P1 and stores the time that this occurs as t_{final2} at step 430.

Having acquired the raw data necessary to determine whether the degree of backlash necessitates declaration of a service condition, the controller 20 proceeds to use the raw data at steps 435 and 440 by setting a value t1 equal to the time required to go from position P1 to P2 and a value t2 equal to the time required to go from position P2 to position P1. These values are then used at step 445 to calculate the time difference t_{error} between the travel to P2 and the return to P1. If the difference is less than a predetermined time value $t_{service}$, the controller 20 decides at step 450 that a service condition does not exist and continues with other processing at step 455. If, however, the value of t_{error} is equal to or greater than $t_{service}$, the controller 20 determines at step 450 that a service condition exists and provides a signal indicating the need for service at step 460 before continuing with other processing at step 455. The indication of a need for service can take on any of the forms described above.

FIGs. 7 and 8 are schematic illustrations of a packaging machine system, such as the one disclosed in the aforementioned '546 application and '414 application, which may use the foregoing control system. Any of the referenced modules may be used with the presently disclosed diagnostic system.

As shown, the packaging machine, shown generally at 500, includes an upper endless belt conveyor 505 and a lower endless belt conveyor 510. The upper endless belt conveyor 505 is driven by a pair of pulley wheels that are indirectly driven by a respective servomotor through a gear mechanism, drive belt, or the like. The lower endless belt conveyor is also driven by a pair of pulley wheels that are indirectly driven by a respective servomotor. The conveyors may be constructed in accordance with the teachings of U.S.S.N. 08/282,981, filed July 29, 1994, which is incorporated herein by reference.

A plurality of processing stations 600, 610, and 615 are disposed about the periphery of the endless belt conveyors 505 and 510. The processing stations 600, 610, and 615 each have their respective mechanical components driven by one or more servomotors that control the movable components of the station in accordance with predetermined motion profiles that are stored in the controller 20. These predetermined motion profiles may be modified during their execution in accordance with the teachings of co-pending U.S.S.N. ____________, entitled "Control System Having Error Correction Apparatus" (Attorney Docket No. 10623US02), filed concurrently herewith and incorporated by reference.

The lower conveyor 510 receives erected carton blanks at end 620 and transports the carton blanks to processing station 600 in one or more indexed movements. Each indexed movement is executed in accordance with the

predetermined motion profile stored in the controller 20 for the lower conveyor 510.

Processing station 600 may include a lifter mechanism and a bottom sealer mechanism. The lifter mechanism may be constructed in accordance with the teachings of U.S.S.N. 08/315,410 filed September 28, 1994 (Attorney Docket No. 10325US01; Corporate Docket No. TRX-0043) entitled "Belt Driven Linear Transport Apparatus for a Packaging Machine", and U.S.S.N. 08/315,401 filed September 28, 1994 (Attorney Docket No. 10602US01; Corporate Docket No. TRX-0044) entitled "Lifter Mechanism Employing a Carton Gripper and Carton Bottom Seal Configuration for Same". The bottom sealer mechanism may be constructed in accordance with the teachings of U.S.S.N. 08/315,412 filed September 28, 1994 (Attorney Docket No. 10454US01; Corporate Docket No. TRX-0082), entitled "Ultrasonic Carton Sealer". Each of these applications is hereby incorporated by reference.

In operation, the lifter mechanism transports the erected cartons in groups from the lower conveyor 510 to the upper conveyor 505. At the upper conveyor 505, the bottoms of the cartons are sealed, for example, with the previously noted sealing apparatus using ultrasonic energy.

The upper conveyor 505 then transports the cartons to processing station 610, the control system 20 correcting for any errors caused by the intermediate drive mechanism by employing the apparatus set forth in the foregoing co-pending application (Attorney Docket No. 10632US02). Processing station 610 may include a fill lifter mechanism, a plurality of filling nozzles respectively associated with each of the cartons, and a top sealer. The fill lifter may be

constructed in accordance with the teachings of the aforementioned '410 application (Attorney Docket No. 10325US01; Corporate Docket No. TRX-0043) and '401 application (Attorney Docket No. 10602US01; Corporate Docket No. TRX-004), while the top sealer may be constructed in accordance with the teachings of the aforementioned '412 application (Attorney Docket No. 10454US01; Corporate Docket No. TRX-0082). At processing station 610, the fill lifter lifts the cartons to a position proximate the fill nozzles and gradually lowers the cartons as product is dispensed into them. Once the cartons have been filled, the top sealer seals the carton into the familiar gabled top configuration.

After the tops of the cartons have been sealed, the upper conveyor 505 transports the cartons to processing station 615. Processing station 615 may include a bottom forming mechanism and an outfeed mechanism. The bottom forming mechanism, for example, may be constructed in accordance with the teachings of U.S.S.N. 08/315,403 filed September 28, 1994 (Attorney Docket No. 10599US01; Corporate Docket No. TRX-0064), entitled "Vacuum Operated Bottom Former", and the outfeed mechanism may be constructed in accordance with the teachings of either U.S.S.N. 08/315,409 filed September 28, 1994 (Attorney Docket No. 10594US01; Corporate Docket No. TRX -0113), entitled "Apparatus for Transferring Containers to a Moving Conveyor") or U.S.S.N. 08/315,404 filed September 28, 1994 (Attorney Docket No. 10610US01; Corporate Docket No. TRX-0118), likewise entitled "Apparatus for Transferring Containers to a Moving Conveyor". At processing station 615, the bottom forming mechanism forms the bottom of the cartons to allow them to sit properly in an erect state. After the bottoms have been formed, the outfeed mechanism

transfers the cartons to a distribution system, shown here as a dual line conveyor 625.

The use of gearboxes and cams, driven by constant velocity motors, to effect mechanism motions usually constrains the mechanism motions of the moving components of the packaging machine to constant velocity, or sinusoidal acceleration, or "modified sine" acceleration profiles. The present system is not constrained in this fashion. Rather, the present system facilitates implementation of motion profiles that enable, not just the movement of a mechanism from a start position to an end position in time t, but also profiles with accelerations and velocities that can be tailored to minimize the constraints that, for example, servo-amplifier current and voltage limits or product viscosities impose.

The foregoing system may be utilized in connection with any predetermined motion profile associated with any movable component of the packaging system. As such, the particular aspects of the predetermined motion profiles of the components are not necessarily important to the practice of the present invention. Nevertheless, it may be useful to describe some of the motion profiles that may be implemented using the disclosed system.

Motion profiles to be executed by the disclosed system using Socapel products, are coded as sequences of positions p_i that vary from 0 to 1. Prior to execution of any particular motion profile the PAM 30:

1) multiplies each p_i by a signed (+/-) scale factor equivalent to the maximum angular distance that we want the motor to rotate during any one machine cycle; and

2) adds to each scaled p_i a signed offset magnitude that shifts the initial p_i (and all subsequent p_i) forward or backward from the motor zero position.

The PAM 30 then assumes:

1) that the sequence of positions to be achieved by the motor during runtime will be spread out over the time of one machine cycle; and

2) the time interval between two adjacent p_I is the same as any other two adjacent p_I.

Then the PAM 30 associates:

p_0 with t_0

p_1 with $t_1 = t_0 + \Delta t$

p_2 with $t_2 = t_1 + \Delta t$

...

p_f with $t_f = t_f\text{-}1 + \Delta t$

where

Δt = machine cycle time/(#p_I -1).

An ideal motion profile may be defined in terms of the accelerations (sinusoidal, cosinusoidal, and constant) and positions that the motor is to achieve over the time of a machine cycle. Data points along the ideal position, velocity, and acceleration profiles may then be selected to preserve the shape of the acceleration curve. In practice, this may be between 90 and 360 samples per profile.

To ensure that the PAM 30 and the servomotors 90 are programmed with position profiles that they can execute smoothly, it is presently desirable to create position profiles that are derived from sequences of constant accelerations. To achieve this, the velocity profile that satisfies the initial acceleration and position profiles is utilized. Assuming that each velocity (v_i) will be achieved via a constant acceleration, each necessary acceleration (s_i) is calculated. The position points p_i are then determined based on the following equation:

$$p_I = p_{I-1} + (v_{I-1} * \Delta t) + (\tfrac{1}{2} * s_{I-1} * \Delta t)^2.$$

The following motion profiles may be implemented using the foregoing method.

Infeed Conveyor Motion Profile:

The motion profile for the infeed (or lower) conveyor 510 is set forth in FIGs. 9-11, which illustrate the position, velocity, and acceleration profiles respectively. Sinusoidal accelerations are utilized, instead of more rapidly rising accelerations, to minimize jerking of the pulleys. The time of deceleration is made longer than the acceleration time to reduce the magnitude of deceleration. Higher pulley decelerations may cause the conveyor band to slip forward with respect to the pulley when the band is loaded with cartons thereby causing indexing errors.

Upper Conveyor Motor Profile:

The upper conveyor 505 motion profile may proceed in accordance with the motion profile illustrated in FIGs. 12-14. This profile is basically a 1/3rd, 1/3rd, 1/3rd trapezoidal velocity profile. Higher accelerations may outstrip the ability of the servo amplifier to supply current and voltage. During the time of any acceleration (or deceleration) 20% of the time is spent ramping up to constant acceleration and 20% of the time is spent ramping down to zero acceleration. The ramping of accelerations was implemented to limit jerking of the driven mechanisms.

Lifter Motion Profile:

The lifter mechanism of station 600 is constructed in accordance with the teachings of the previously noted '410 application (Attorney Docket No. 10325US01; Corporate Docket No. TRX-0043) and includes a bottom lifter and

top pre-folder, each driven by a respective servomotor. The motion profiles of the lifter mechanism are set forth in FIGs. 15-17.

The motion profile for the bottom lifter is set forth in FIGs. 15-17 and consists of three moves. The first motor move lifts the forks up to the bottoms of the cartons in the lower conveyor band 510. The second move drives the forks up through the lower conveyor band 510 and into the upper conveyor band 515 so that the bottom sealing areas are of the cartons in the same plane as the jaws of the horn and anvil of the ultrasonic bottom sealer. The third move returns the forks down to their home position. The third move begins when the jaws of the sealer make contact with the bottom sealing areas of the cartons.

Each move of this profile is basically a 1/3rd, 1/3rd, 1/3rd trapezoidal velocity profile. However, during the time of any acceleration (or deceleration) 20% of the time is spent ramping up to constant acceleration and 20% of the time is spent ramping down to zero acceleration. The ramping of accelerations was implemented to limit jerking of driven mechanisms.

The motion profile for the top pre-folder is set forth in FIGs. 18-20 and consists of four moves. The first motor move drives the prefolder forks down through the upper conveyor band 505 into the lower conveyor band 510 to the level of the carton tops. Since the bottom lift forks arrive at the carton bottoms at the same time, the bottom lift forks and the prefolder forks secure the cartons. The second move draws the prefolder back up through the upper conveyor band 405. This second move is similar to the second move of the bottom lift but in the opposite direction so that the cartons remain secure in the grips of both sets of forks. The third move drives the prefolder down a length sufficient to keep

the bottom sealing surfaces of the cartons in the same plane as that of the bottom sealer jaws during jaw closure. Without this downward move of the prefolder, the bottom sealing surfaces of the cartons would slide over the sealer jaws during their closure. The third move begins when the sealer jaws have made contact with the bottom sealing surfaces of the carton. The fourth move draws the prefolder clear of the carton tops and up to its home position sometime before the upper conveyor band 505 moves. The retraction move begins after the sealer jaws have firmly gripped the carton bottoms.

Each move of the profiles of FIGs. 18-12 is basically a 1/3rd, 1/3rd, 1/3rd trapezoidal velocity profile. However, during the time of any acceleration (or deceleration) 20% of the time is spent ramping up to constant acceleration and 20% of the time is spent ramping down to zero acceleration. The ramping of accelerations was implemented to limit jerking of the driven mechanisms.

Bottom Sealer Motion Profile:

The bottom sealer of station 600 may be constructed in accordance with the teachings of the previously noted '412 application (Attorney Docket No. 10454US01; Corporate Docket No. TRX-0082). The ultrasonic bottom sealer disclosed therein includes a cam mechanism that is driven by a servomotor.

The motion profile for the bottom sealer is set forth in FIGs. 21-23 and includes two moves. The first motor move rotates the cams so that the sealer jaws close. The first motor move begins far enough in advance so that the jaws make contact with the carton bottoms just after the carton bottoms arrive in the plane of the jaws. The second motor move rotates the cams so that the sealer

jaws open. Each move spends 15% of the move time accelerating, 70% of the move time at constant velocity, and 15% of the move time decelerating. The cams are shaped to move the jaws during the constant velocity portion of the move. Thus, the possibility of adding torques required to move the jaws to torques required to accelerate the cams is avoided.

Each move of this profile is basically a 15%, 70%, 15% trapezoidal velocity profile. However, during the time of any acceleration (or deceleration) 20% of the acceleration time is spent ramping up to constant acceleration and 20% of the acceleration time is spent ramping down to zero acceleration. The ramping of accelerations was implemented to prevent jerking of the driven mechanisms.

Fill Lifter Motion Profile:

The fill lifter of processing station 510 may be constructed in accordance with the teachings of the '410 application (Attorney Docket No. 10325US01; Corporate Docket No. TRX-0043) and the '401 application (Attorney Docket No. 10602US01; Corporate Docket No. TRX-0044). Each of these applications, as previously noted, is incorporated by reference.

The motion profile for the lifter mechanism is set forth in FIGs. 23-25 and includes four moves. The first motor move drives the fill lift up through the upper conveyor band 505 and the cartons into the fill chambers of the filling stations proximate the fill nozzles. The distance moved is sufficient to bring the carton bottoms within a few mm of the bottom of the fill nozzles. The first move drives the lift up as quickly as possible. The accelerations have been

ramped and made as small as possible to both minimize stress on the bands and couplings and to minimize demands on servo amplifier current.

The second move draws the lift down from the fill nozzle. It begins slightly after filling begins. The second move draws the lift down from the fill nozzle at velocities sufficient to keep the fill nozzle close to the level of the liquid as the liquid is dispensed. For hygienic reasons, the lifter mechanism moves down fast enough to prevent the liquid level from rising to levels that immerse the outside of the nozzles in the liquid. To minimize splashing and foam, the lift mechanism moves down slow enough to keep the liquid level close to the bottom of the nozzles. The second move ends when the top sealing areas of the cartons are in the plane of the top sealer jaws.

The third move drives the fill lift up a length sufficient to keep the top sealing surfaces of the cartons in the same plane as that of the top sealer jaws during jaw closure. Without this upward move of the fill lift, the top sealing surfaces of the carton may slide under the sealer jaws during their closure. The third move begins when the sealer jaws have made contact with the bottom sealing surfaces of the carton.

The accelerations of the third move have been limited to $\sim .5$ g to assist in preventing carton bulging and food spray. Food sprays are undesirable for hygiene reasons. Bulging cartons are likewise undesirable. First, they are difficult to handle without damage, because the bulging implies an internal pressure that can abet carton leaks. Further, bulging implies extra oxygen in the carton that can degrade product taste.

The fourth move draws the fill lift down to its home position sometime before the upper conveyor band 405 indexes. The retraction move begins after the sealer jaws of the top sealer have released the carton tops.

Each move of this profile is basically a 40%, 20%, 40% trapezoidal velocity profile. However, during the time of any acceleration (or deceleration) 20% of the time is spent ramping up to constant acceleration and 20% of the time is spent ramping down to zero acceleration. The ramping of accelerations was implemented to limit jerking of the driven mechanisms.

Fill Pump Motion Profile:

The processing station 610 may include a fill pump that pumps liquid from a storage tank into the cartons. The fill pump includes a piston that reciprocate back and forth to alternately fill and empty a pump chamber. The piston may be driven by a screw mechanism that, in turn, is driven by a servomotor.

The motion profile for the fill pump is illustrated in FIGs. 26-28 and includes two moves. The first move, the fill move, drives the pump piston forward to drive liquid down through the fill nozzle and into the carton. The second move, the recharge move, drives the pump piston backward to draw liquid from the storage tank into the pump chamber.

The aim of the fill move is to get liquid into the carton as fast as possible. However, pump velocities must be kept below those velocities that cause unacceptable splash and foaming. During the first part of the fill move (the "acceleration" part of the move) the velocities can be, and are, increased

dramatically as the liquid depth increases. After some characteristic depth is achieved, the rate of increase in liquid velocities must be slowed to keep splash and foaming to acceptable levels. This defines the second part (the "almost-constant-velocity" part) of the move.

During the third part of the fill move, deceleration is done as quickly as possible. The magnitude of the deceleration is related to the time required to close the outlet valve so that the liquid flow reaches zero at the same time that the outlet valve is closed. If the valve closes too early, an incorrect volume will be delivered to the package. Additionally, if the pump piston continues its stroke after the outlet valve closes, the increased fluid pressures will force a spray of liquid through the pump housing and diaphragm and out to various parts of the machine. Such an event compromises the hygiene of the machine. If the valve closes too late, then air will enter the nozzle and the pump chamber which will, again, cause an incorrect volume to be delivered to the package. The faster the deceleration, the more precise the timing of the valve closing has to be.

During the recharge move, accelerations and velocities are limited to prevent gasses from coming out of solution due to pressure reductions. Gas bubbles in the fill pump chamber may cause inaccurate liquid volumes to be delivered to the package. Pump accelerations are kept below those that keep flow accelerations below 1 g. Pump velocities are kept below those that enable flow velocities of 2 m/s or greater in the recharge pipes.

Top Sealer Motion Profile:

The top sealer of station 610 is, for example, constructed in accordance with the teachings of the '412 application (Attorney Docket No. 10454US01; Corporate Docket No. TRX-0082). That application, as noted above, is incorporated by reference.

The motion profile for the top sealer is set forth in FIGs. 29-31 and includes two moves which drive the cam. The first move of this profile closes the top sealer jaws. It is an atypical move consisting of three polynomial splines. The first spline rotates the cams so that the jaws make contact with the top sealing areas of the cartons simultaneously with their arrival at the jaws. The cams arrive at that point with a very low velocity. The low cam velocity is selected so that the jaw velocities are small enough to give refold mechanisms, such as those described in U.S.S.N. 08/315,400 filed September 28, 1994 (Attorney Docket No. 10455US01; Corporate Docket No. TRX-0047), entitled "Apparatus for Sealing the Fin of a Gabled Container", incorporated herein by reference, time to shape the carton tops for proper folding. At the same time it is desirable to have a velocity greater than zero so that the subsequent acceleration can be instituted without having to overcome static friction.

The second spline of the move rotates the cams until the jaws, and thus the carton tops, are about 5 mm apart. It is desired that this move last 100ms to continue giving time to allow the refold mechanisms to fold the cartons and, further, to allow excess air to escape from the cartons. It is also desired that the velocity at the end of the second spline be as low as possible while still enabling the jaws to finish closing in the next 100ms via the third spline. The low velocity at the end of the second spline (and, thus, at the beginning of the third

spline) extends the time for air escapement into the third spline. The third spline has to decelerate as fast as possible to complete the cam rotation and jaw closing in the allotted 100ms.

The second move opens the top sealer jaws and is the same as the move that opens the bottom sealer jaws. That is, the move spends 15% of the move time accelerating, 70% of the move time at constant velocity, and 15% of the move time decelerating. During the time of any acceleration (or deceleration) 20% of the time is spent ramping down to zero acceleration. The ramping of accelerations is implemented to reduce jerking of the driven mechanisms.

Bottom Former Lift Motion Profile:

Processing station 615 includes a bottom former that forms a flattened seating area from the gabled bottom of each carton. The bottom former may be constructed in accordance with the teachings of the '403 application (Attorney Docket No. 10599US01; Corporate Docket No. TRX-0064). The bottom former thus includes a cup array that forms the carton bottoms and, further, transfers the cartons from the upper conveyor 505 to the outfeed mechanism. The cup array is moved by a linear activator (lifter) that is driven by a servomotor.

The motion profile for the lifter is set forth in FIGs. 32-34. The motion profile begins with the cartons already in the cups of the array. At this point the cups can move down whereas the cartons can not move down any further. The first motor move drives the cups down a sufficient distance to allow the ejecting mechanisms to drive the cartons from the cups and assure that the top edges of cups cannot "trip" the cartons when they are pushed horizontally out of the

station. The cups have to remain at that level long enough for the pusher of the outfeed mechanism to shove the cartons out and then retract back out of the upward path of the cups.

The second move of the profile begins as soon as the pushers are clear of the upward path of the cups. The second move drives the lift up as fast as the servo amplifier can allow. Within the accelerations (or decelerations) of this move 20% of the time is spent ramping up to constant acceleration and 20% of the time is spent ramping down to zero acceleration. The ramping of accelerations is implemented to reduce jerking of the driven mechanisms. After the lift has finished the move up, it must dwell there long enough to allow the cup vacuum to drive the carton bottoms firmly into the cups.

After the dwell, the third move takes the cup array down as quickly as is necessary to reach a level at which the cartons are below any mechanism that would otherwise collide with the cartons and/or lift when the conveyor indexes. The smallest accelerations that enable the avoidance of collisions are desirable, first, to prevent the cups from leaving the cartons behind and, second, to keep the bottom folds of the carton as tight against the cup bottoms as possible.

The fourth move does not have to cope with any abnormal demands and, thus, is a leisurely drop down to the home position.

Although the present invention has been described with reference to specific embodiments, those of skill in the art will recognize that changes may be made thereto without departing from the scope and spirit of the invention as set forth in the appended claims.

WHAT IS CLAIMED IS:

1. A control system for driving a movable component of an apparatus comprising:
   a) a servomotor connected to drive the movable component from a start position to an end position;
   b) a controller for directing the servomotor to drive the movable component in accordance with a predetermined motion profile, the predetermined motion profile defining motion characteristics of the movable component as the movable component moves from the start position to the end position within a predetermined time frame, the controller monitoring torque load on the servomotor within the predetermined time frame and comparing the monitored torque load with a predetermined maximum service torque value and a predetermined minimum service torque value to determine whether a service condition exists;
   c) a status indicator responsive to detection of a service condition by the controller to provide an indication of the service condition.

2. A control system as claimed in Claim 1 wherein the status indicator is an alphanumeric display.

3. A control system as claimed in Claim 1 wherein the status indicator is a panel lamp.

4. A control system as claimed in Claim 1 wherein the status indicator is a printer.

5. A control system as claimed in Claim 1 wherein the status indicator is disposed at a location remote from the apparatus.

6. A control system as claimed in Claim 5 wherein the status indicator comprises a computer terminal disposed at the remote location and in data communication with the controller.

7. A control system as claimed in Claim 1 and further comprising an intermediate drive mechanism connecting the servomotor to the movable component.

8. A control system as claimed in Claim 7 wherein the intermediate drive mechanism comprises a gear box connected between the movable component and the servomotor.

9. A control system as claimed in Claim 7 wherein the intermediate drive mechanism comprises a belt connected between the movable component and the servomotor.

10. A control system as claimed in Claim 1 wherein the controller comprises:

a) a servo amplifier connected to drive the servomotor; and

b) a programmable axis manager in communication with the servo amplifier.

11. A control system as claimed in Claim 10 wherein the controller further comprises a programmable logic controller in communication with the programmable axis controller.

12. A control system as claimed in Claim 7 wherein the controller comprises:

a) a servo amplifier connected to drive the servomotor; and

b) a programmable logic controller in communication with the servo amplifier.

13. A control system as claimed in Claim 12 wherein the controller further compares the monitored torque load with a predetermined maximum torque load value and performs an emergency stop operation on the servomotor if the monitored torque load exceeds the maximum torque load value.

14. A control system for driving a movable component of an apparatus comprising:

a) a servomotor connected to drive the movable component from a start position to an end position;

b) a controller for directing the servomotor to drive the movable component in accordance with a predetermined motion profile, the

predetermined motion profile defining motion characteristics of the movable component as the movable component moves from the start position to the end position within a predetermined time frame, the controller monitoring torque load on the servomotor at a plurality of times within the predetermined time frame and comparing the measured torque loads at the plurality of times with respective predetermined maximum service torque values to determine whether a service condition exists;

c) a status indicator responsive to detection of a service condition by the controller to provide an indication of the service condition.

15. A control system as claimed in Claim 14 wherein the status indicator is an alphanumeric display.

16. A control system as claimed in Claim 14 wherein the status indicator is a panel lamp.

17. A control system as claimed in Claim 14 wherein the status indicator is a printer.

18. A control system as claimed in Claim 14 wherein the status indicator is disposed at a location remote from the apparatus.

19. A control system as claimed in Claim 14 wherein the status indicator comprises a computer terminal disposed at the remote location and in data communication with the controller.

20. A control system as claimed in Claim 14 and further comprising an intermediate drive mechanism connecting the servomotor to the movable component.

21. A control system as claimed in Claim 20 wherein the controller further monitors torque load on the servomotor at a further plurality of times within the predetermined time frame and compares the measured torque with a predetermined minimum service torque for respective ones of the further plurality of times to determine whether a service condition exists.

22. A control system as claimed in Claim 21 wherein the intermediate drive mechanism comprises a gear box connected between the movable component and the servomotor.

23. A control system as claimed in Claim 21 wherein the intermediate drive mechanism comprises a belt connected between the movable component and the servomotor.

24. A control system as claimed in Claim 14 wherein the controller further compares the measured torque with a predetermined minimum service

torque for the respective ones of the further plurality of times to determine whether a service condition exists.

25. A control system as claimed in Claim 14 wherein the controller comprises:

a) a servo amplifier connected to drive the servomotor; and

b) a programmable axis manager in communication with the servo amplifier.

26. A control system as claimed in Claim 25 wherein the controller further comprises a programmable logic controller in communication with the programmable axis controller.

27. A control system as claimed in Claim 14 wherein the controller comprises:

a) a servo amplifier connected to drive the servomotor; and

b) a programmable logic controller in communication with the servo amplifier.

28. A control system as claimed in Claim 14 wherein the controller further compares the monitored torque load with a predetermined maximum torque load value and performs an emergency stop operation on the servomotor if the monitored torque load exceeds the maximum torque load value.

29. A packaging machine comprising:

a) a plurality of packaging stations, each of the packaging stations executing one or more processes to fill and seal a plurality of packages;

b) a conveyor for transporting the plurality of packages between the plurality of packaging stations;

c) a servomotor connected to drive at least one movable component of at least one of the plurality of packaging stations, the servomotor connected to drive the at least one movable component from a start position to an end position;

d) a controller for directing the servomotor to drive the at least one movable component in accordance with a predetermined motion profile, the predetermined motion profile defining motion characteristics of the at least one movable component as the at least one movable component moves from the start position to the end position within a predetermined time frame, the controller monitoring torque loads on the servomotor at a plurality of times within the predetermined time frame and comparing the measured torque loads at the plurality of times with respective predetermined maximum service torque values to determine whether a service condition exists;

e) a status indicator responsive to detection of a service condition by the controller to provide an indication of the service condition.

30. A packaging machine as claimed in Claim 29 wherein the status indicator is an alphanumeric display.

31. A packaging machine as claimed in Claim 29 wherein the status indicator is a panel lamp.

32. A packaging machine as claimed in Claim 29 wherein the status indicator is a printer.

33. A packaging machine as claimed in Claim 29 wherein the status indicator is disposed at a location remote from the apparatus.

34. A packaging machine as claimed in Claim 33 wherein the status indicator comprises a computer terminal disposed at the remote location and in data communication with the controller.

35. A packaging machine as claimed in Claim 29 and further comprising an intermediate drive mechanism connecting the servomotor to the movable component.

36. A packaging machine as claimed in Claim 35 wherein the controller further monitors torque load on the servomotor at a further plurality of times within the predetermined time frame and compares the measured torque with a predetermined minimum service torque for respective ones

of the further plurality of times to determine whether a service condition exists.

37. A packaging machine as claimed in Claim 36 wherein the intermediate drive mechanism comprises a gear box connected between the movable component and the servomotor.

38. A packaging machine as claimed in Claim 36 wherein the intermediate drive mechanism comprises a belt connected between the movable component and the servomotor.

39. A packaging machine as claimed in Claim 36 wherein the controller further compares the measured torque with a predetermined minimum service torque for the respective ones of the further plurality of times to determine whether a service condition exists.

40. A packaging machine as claimed in Claim 29 wherein the controller comprises:

a) a servo amplifier connected to drive the servomotor; and

b) a programmable axis manager in communication with the servo amplifier.

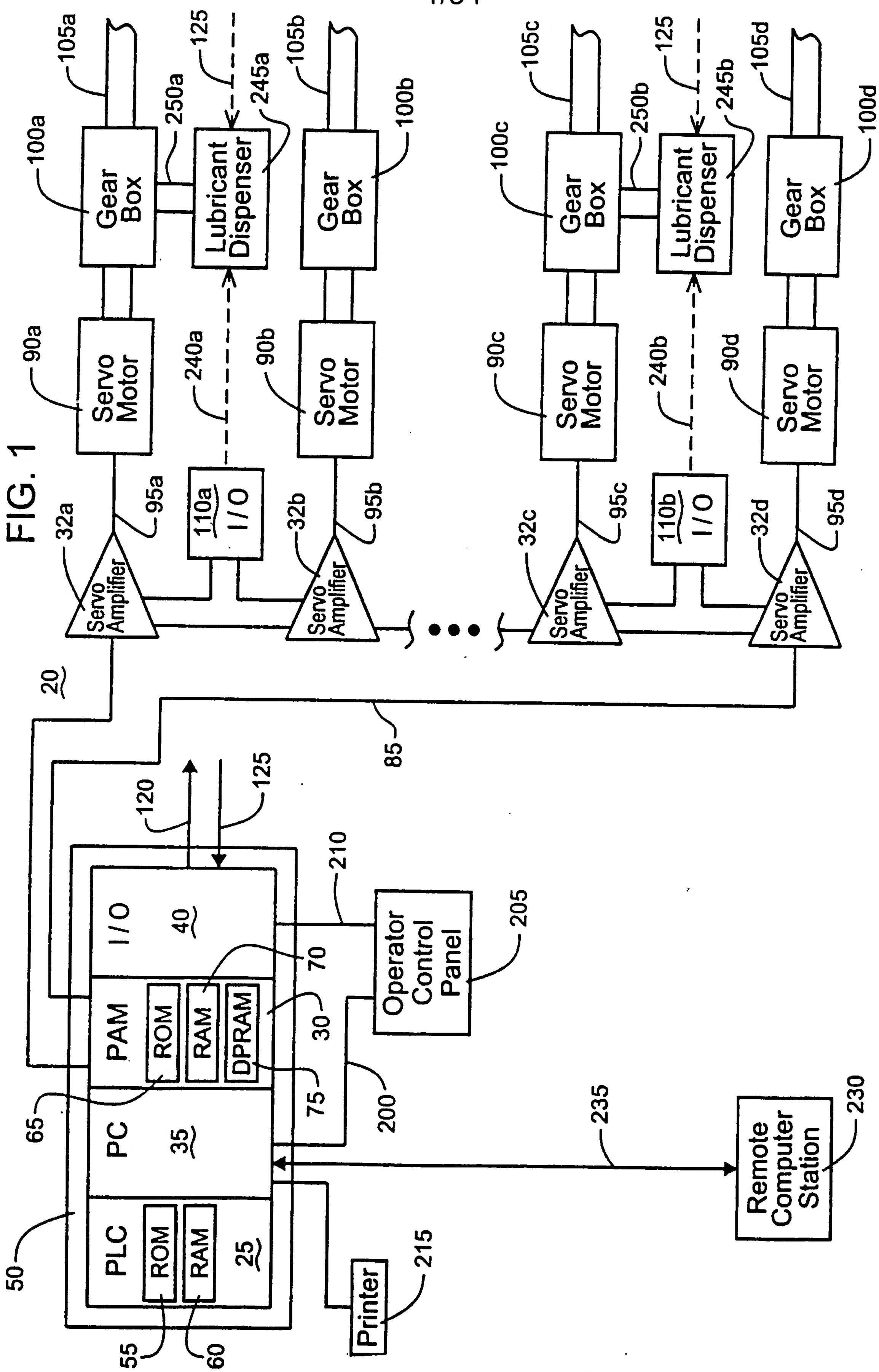
41. A packaging machine as claimed in Claim 40 wherein the controller further comprises a programmable logic controller in communication with the programmable axis controller.

42. A packaging machine as claimed in Claim 35 wherein the controller comprises:

a) a servo amplifier connected to drive the servomotor; and

b) a programmable logic controller in communication with the servo amplifier.

43. A packaging machine as claimed in Claim 29 wherein the controller further compares the monitored torque load with a predetermined maximum torque load value and performs an emergency top operation on the servomotor if the monitored torque load exceeds the maximum torque load value.


Gear Box
Lubricant Dispenser
Servo Motor
Servo Amplifier
I/O
PAM
ROM
RAM
DPRAM
PC
PLC
Operator Control Panel
Printer
Remote Computer Station
105a
125
105b
105c
105d
250a
245a
100a
100b
250b
245b
100c
100d
90a
90b
90c
90d
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110b
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25
55
60
215

FIG. 1

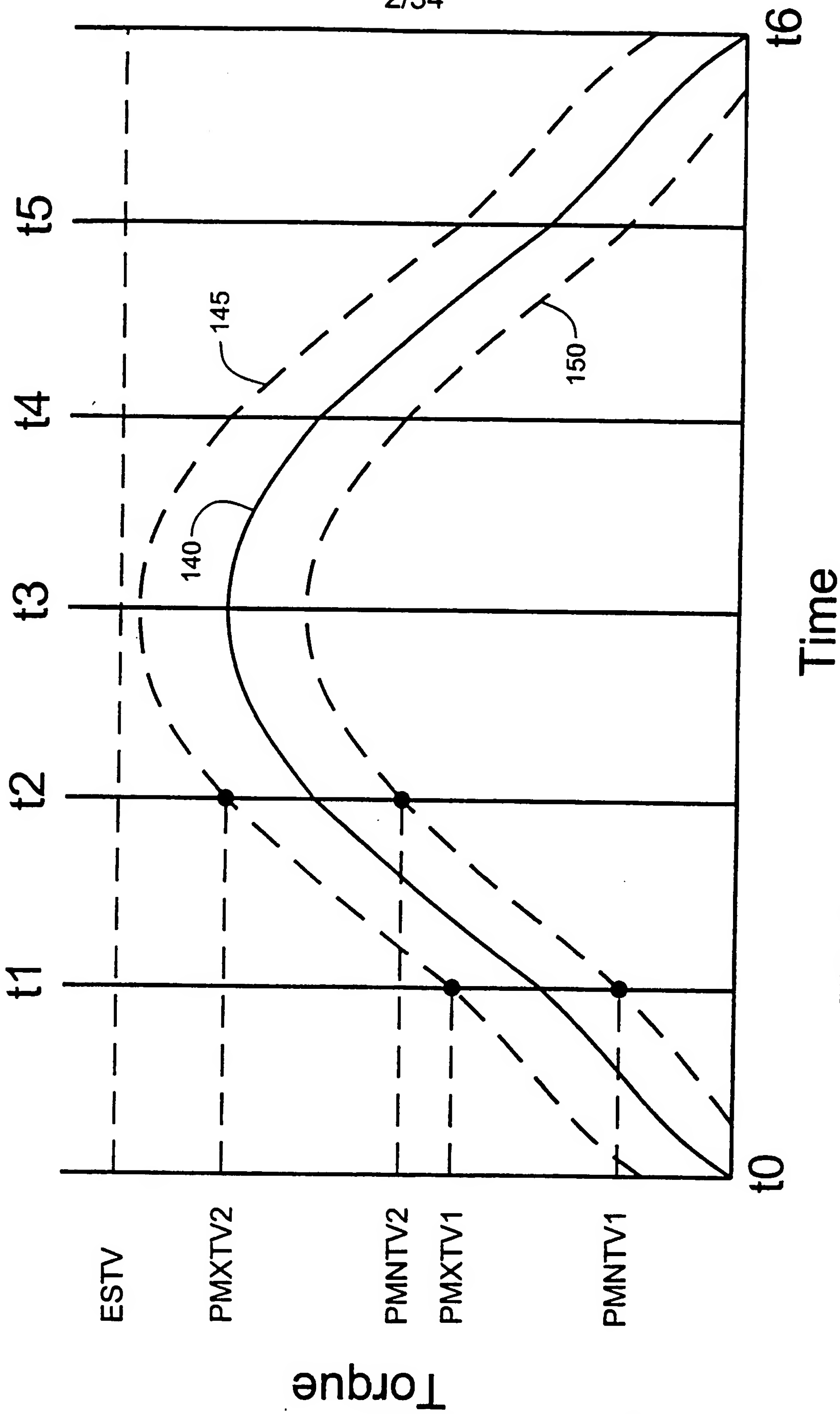
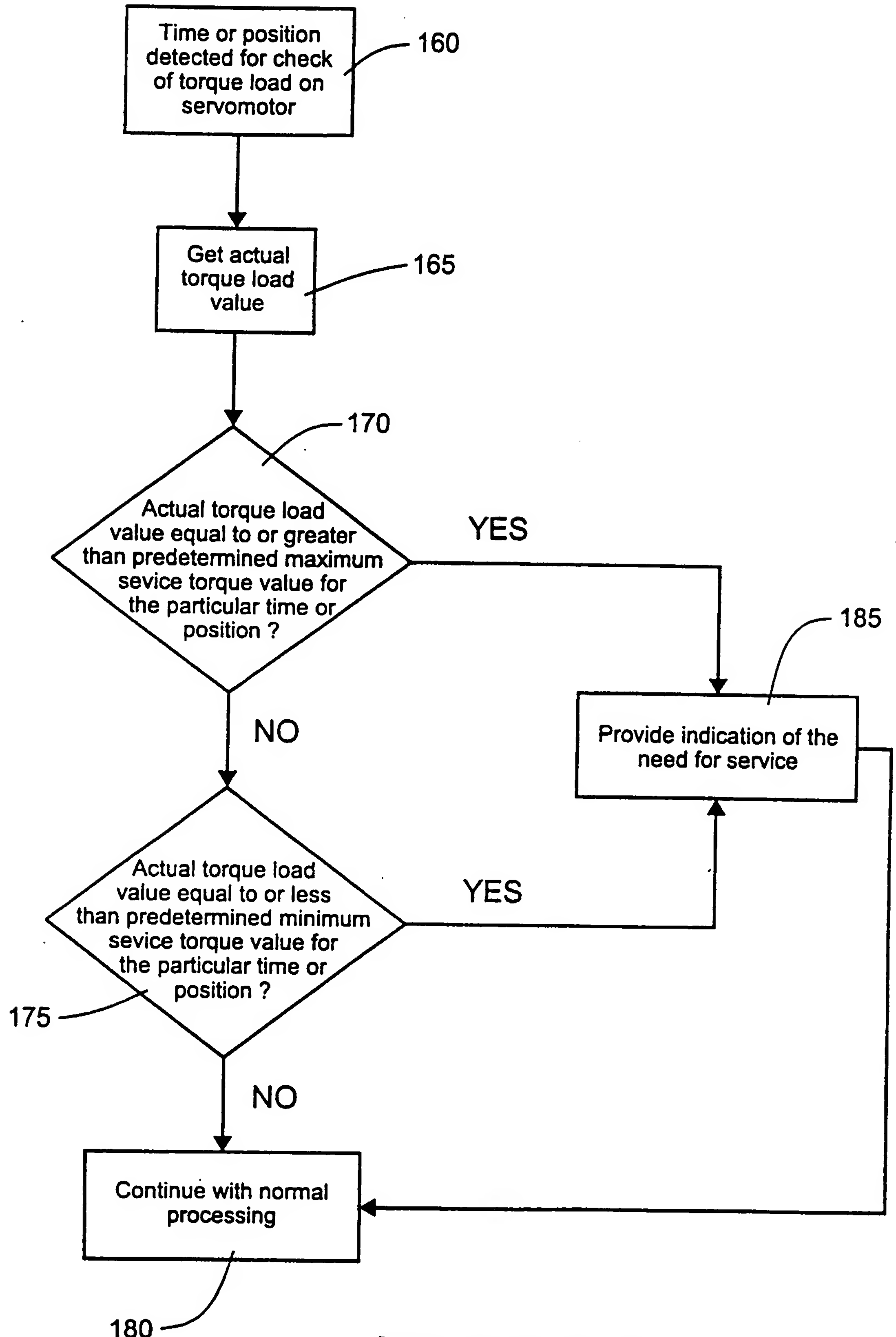

t1
t2
t3
t4
t5
t6
t0
Time
Torque
ESTV
PMXTV2
PMNTV2
PMXTV1
PMNTV1
140
145
150

FIG. 2

FIG. 3


Time or position detected for check of torque load on servomotor
160
Get actual torque load value
165
170
Actual torque load value equal to or greater than predetermined maximum sevice torque value for the particular time or position ?
YES
185
Provide indication of the need for service
NO
Actual torque load value equal to or less than predetermined minimum sevice torque value for the particular time or position ?
YES
175
NO
Continue with normal processing
180

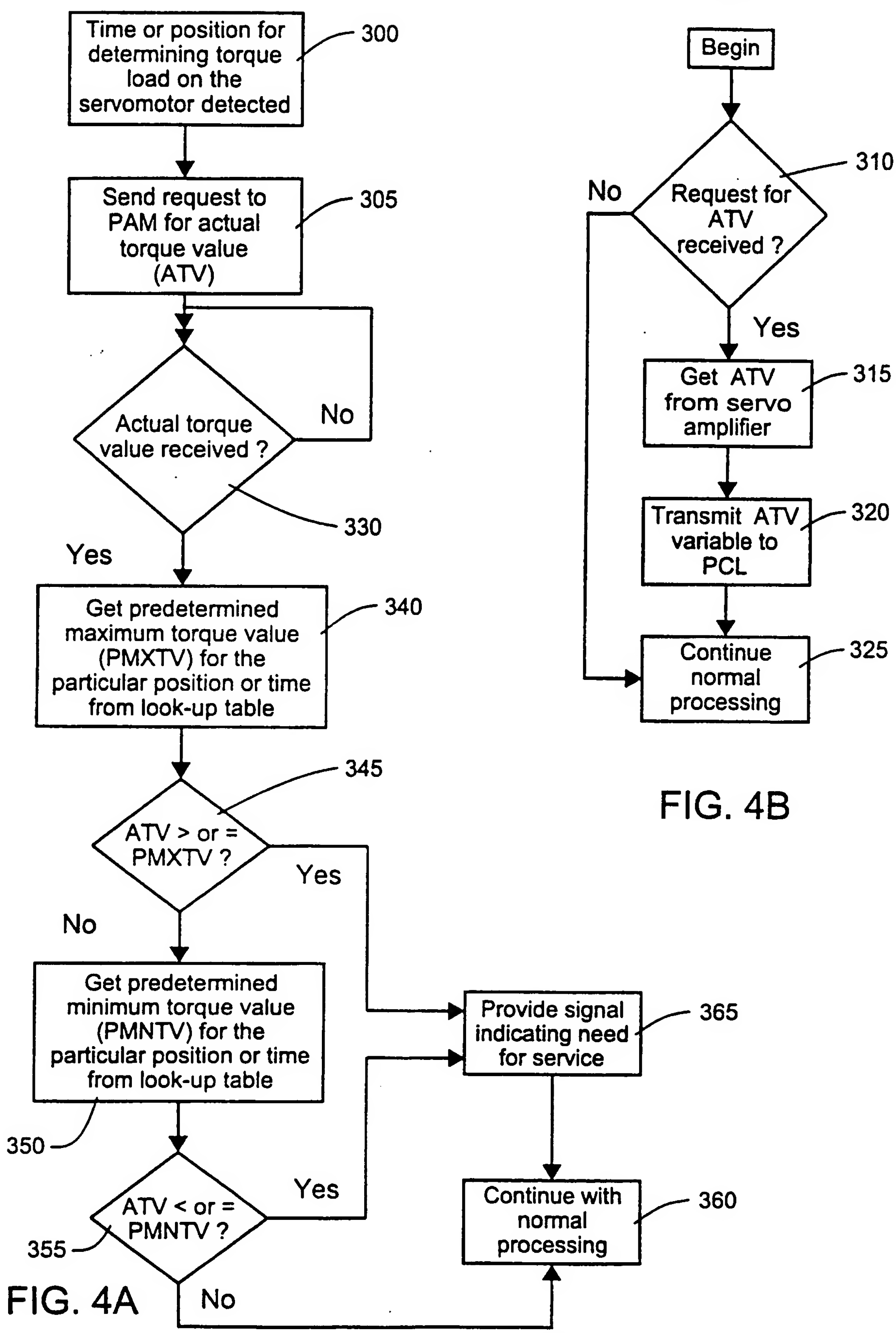
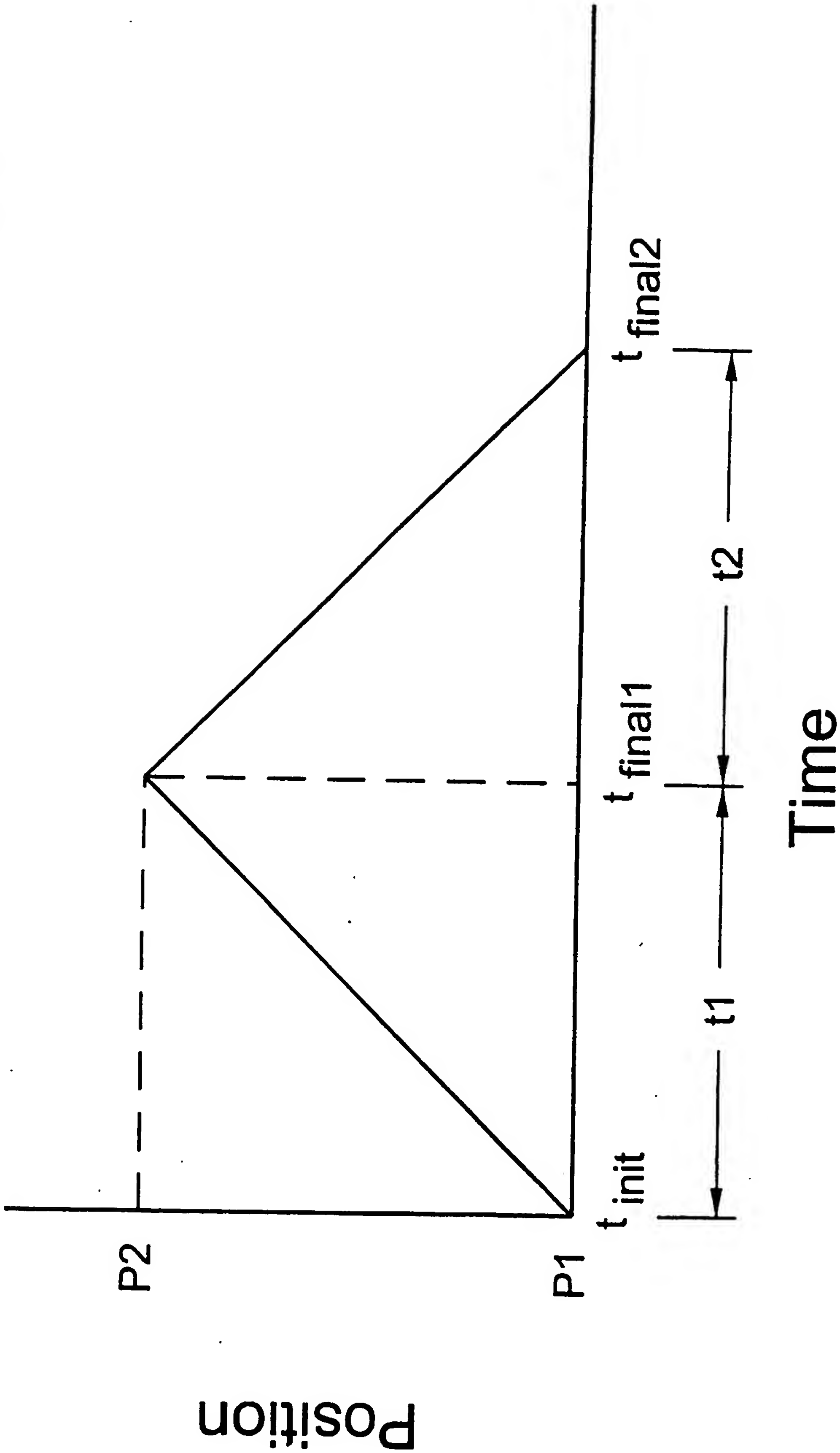

PCL
Time or position for determining torque load on the servomotor detected
300
Send request to PAM for actual torque value (ATV)
305
Actual torque value received ?
No
330
Yes
Get predetermined maximum torque value (PMXTV) for the particular position or time from look-up table
340
345
ATV > or = PMXTV ?
Yes
No
Get predetermined minimum torque value (PMNTV) for the particular position or time from look-up table
350
Provide signal indicating need for service
365
ATV < or = PMNTV ?
Yes
355
No
Continue with normal processing
360
PAM
Begin
Request for ATV received ?
310
No
Yes
Get ATV from servo amplifier
315
Transmit ATV variable to PCL
320
Continue normal processing
325

FIG. 4A

FIG. 4B

FIG. 5



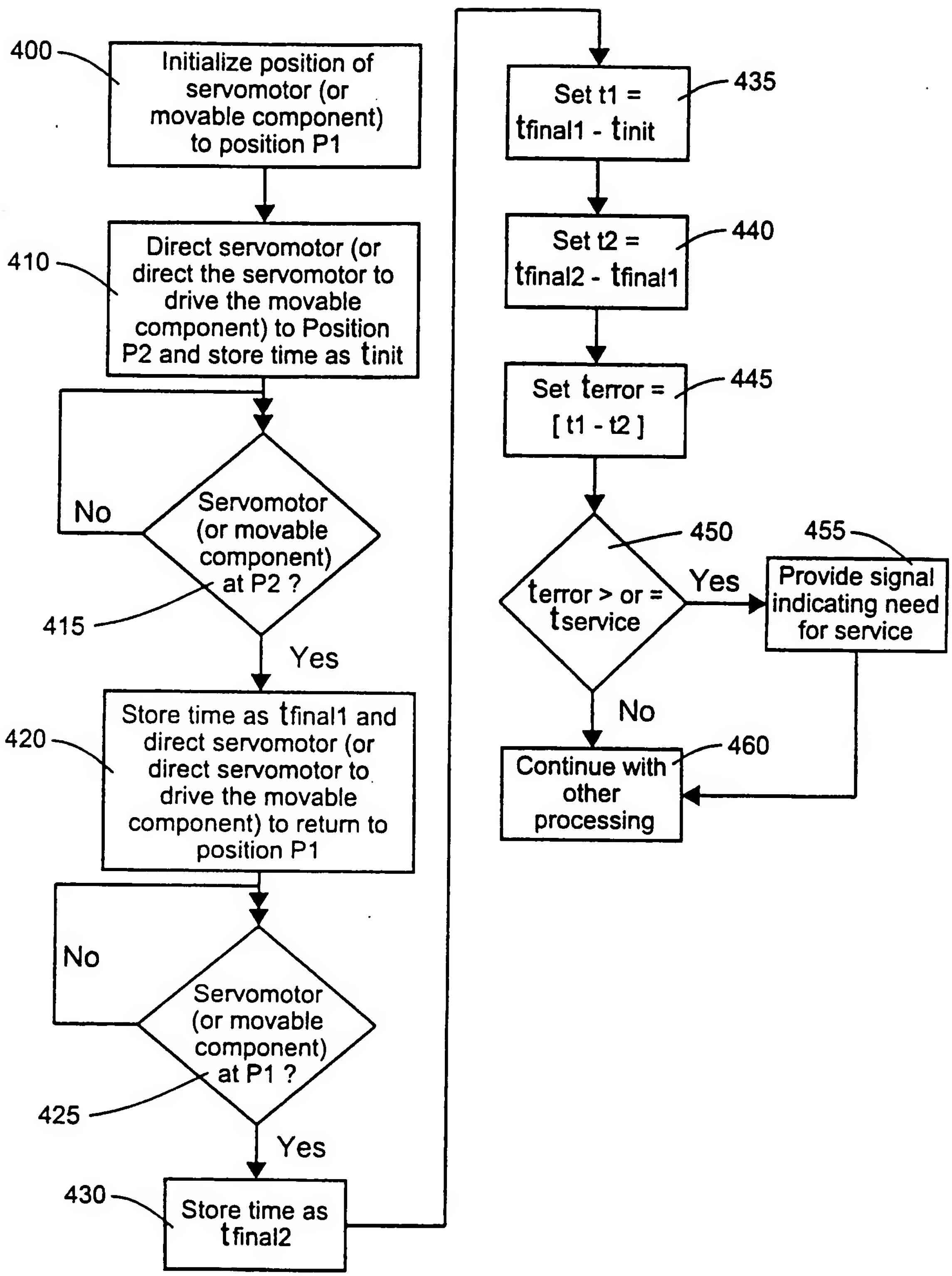

400
Initialize position of servomotor (or movable component) to position P1
410
Direct servomotor (or direct the servomotor to drive the movable component) to Position P2 and store time as tinit
No
Servomotor (or movable component) at P2 ?
415
Yes
420
Store time as tfinal1 and direct servomotor (or direct servomotor to drive the movable component) to return to position P1
No
Servomotor (or movable component) at P1 ?
425
Yes
430
Store time as tfinal2
435
Set t1 = tfinal1 - tinit
440
Set t2 = tfinal2 - tfinal1
445
Set terror = [t1 - t2]
450
terror > or = tservice
Yes
455
Provide signal indicating need for service
No
460
Continue with other processing

FIG. 6

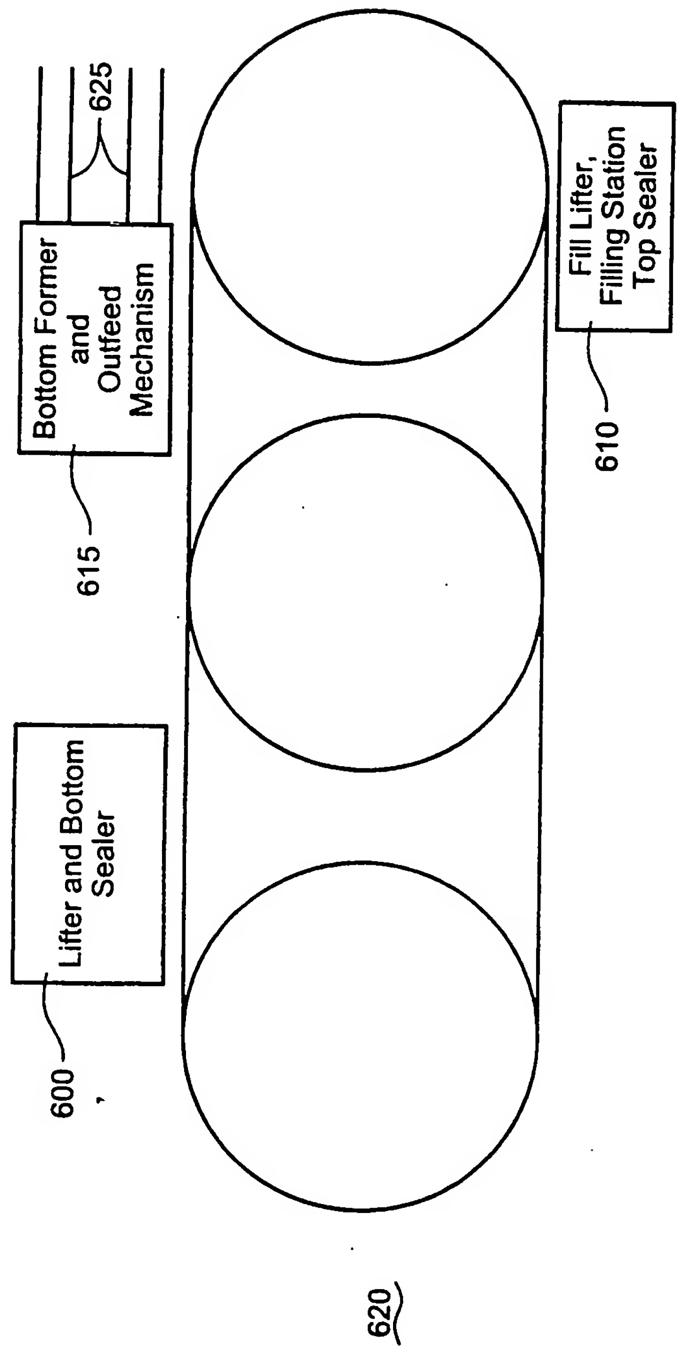

Bottom Former and Outfeed Mechanism
625
615
Lifter and Bottom Sealer
600
Fill Lifter, Filling Station Top Sealer
610
620

FIG. 7

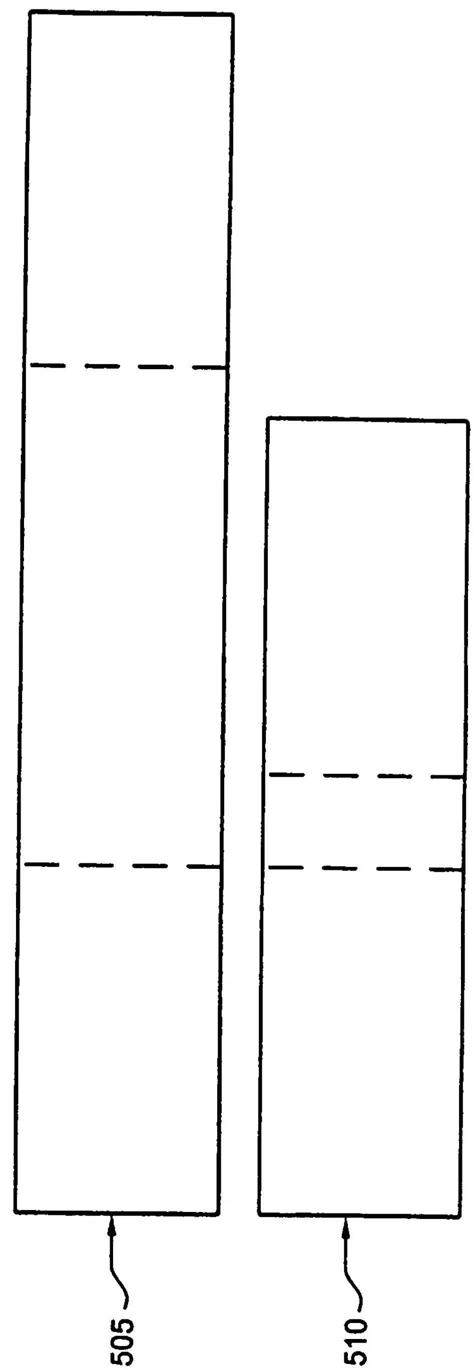

505
510

FIG. 8

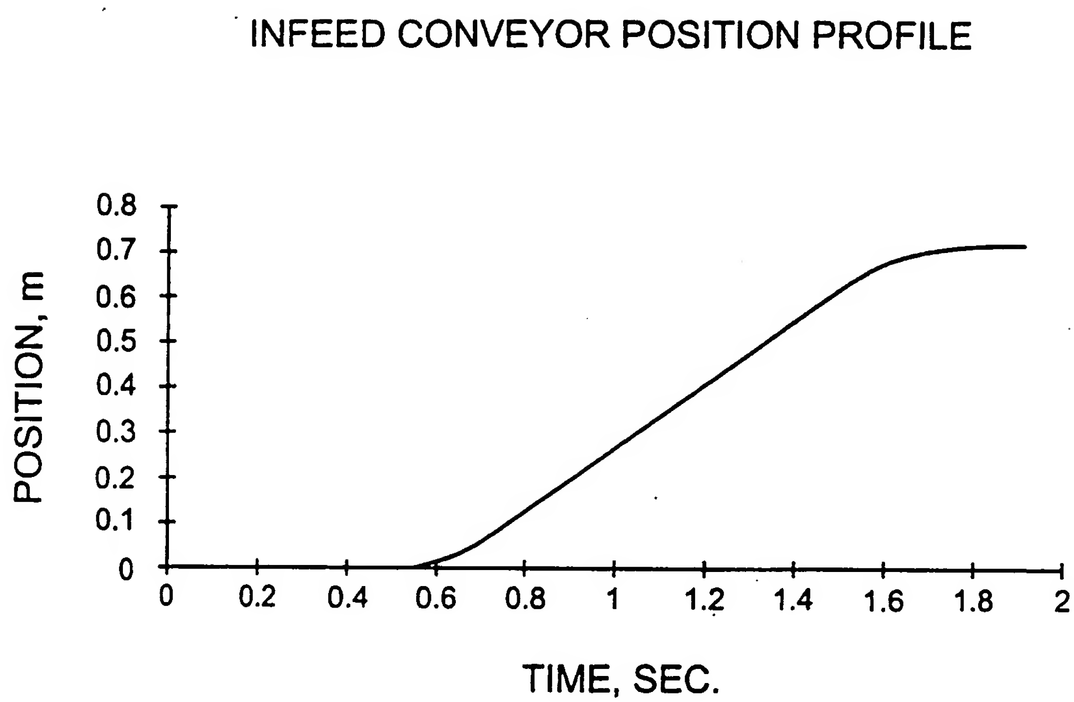

INFEED CONVEYOR POSITION PROFILE
POSITION, m
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
TIME, SEC.

FIG. 9

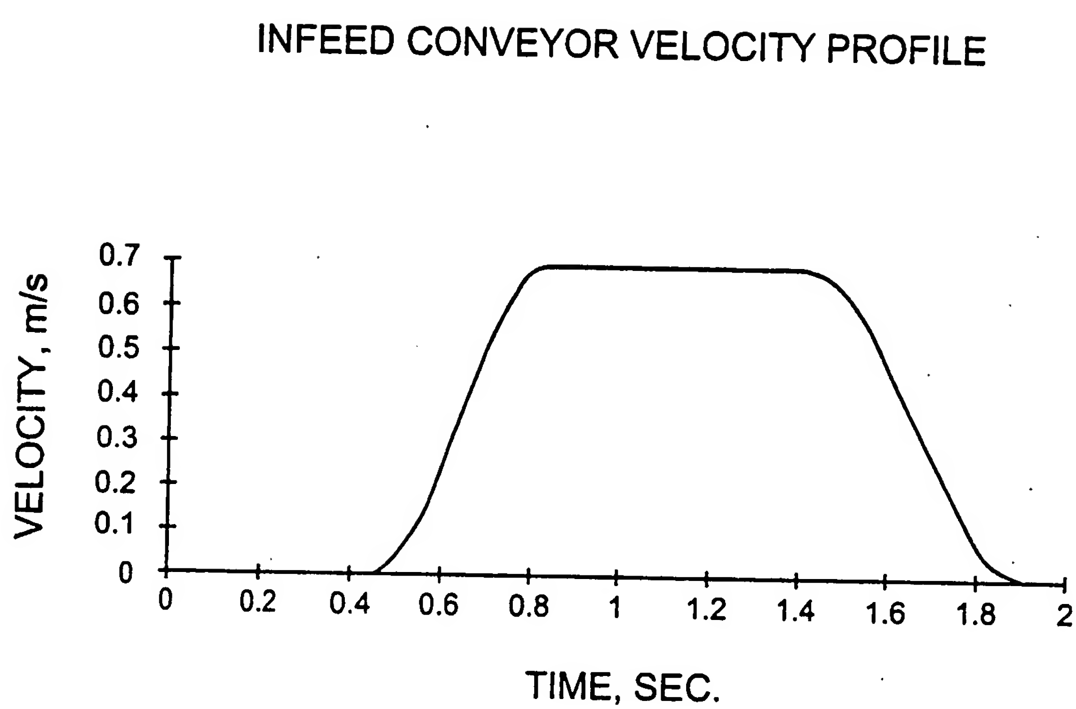

INFEED CONVEYOR VELOCITY PROFILE
VELOCITY, m/s
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
TIME, SEC.

FIG. 10

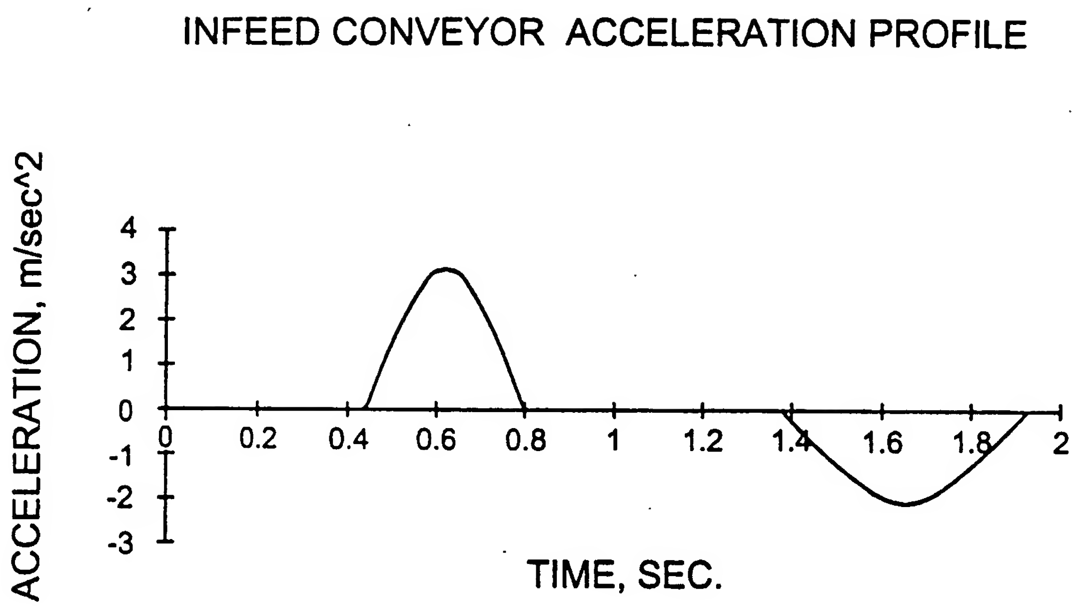

INFEED CONVEYOR ACCELERATION PROFILE
ACCELERATION, m/sec^2
4
3
2
1
0
-1
-2
-3
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
TIME, SEC.

FIG. 11

UPPER CONVEYOR POSITION PROFILE

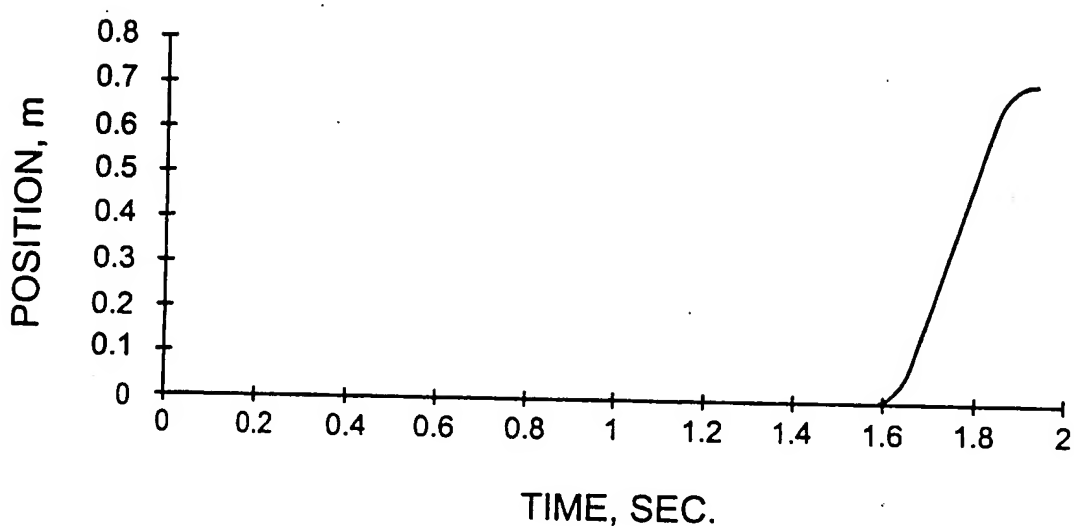


FIG. 12

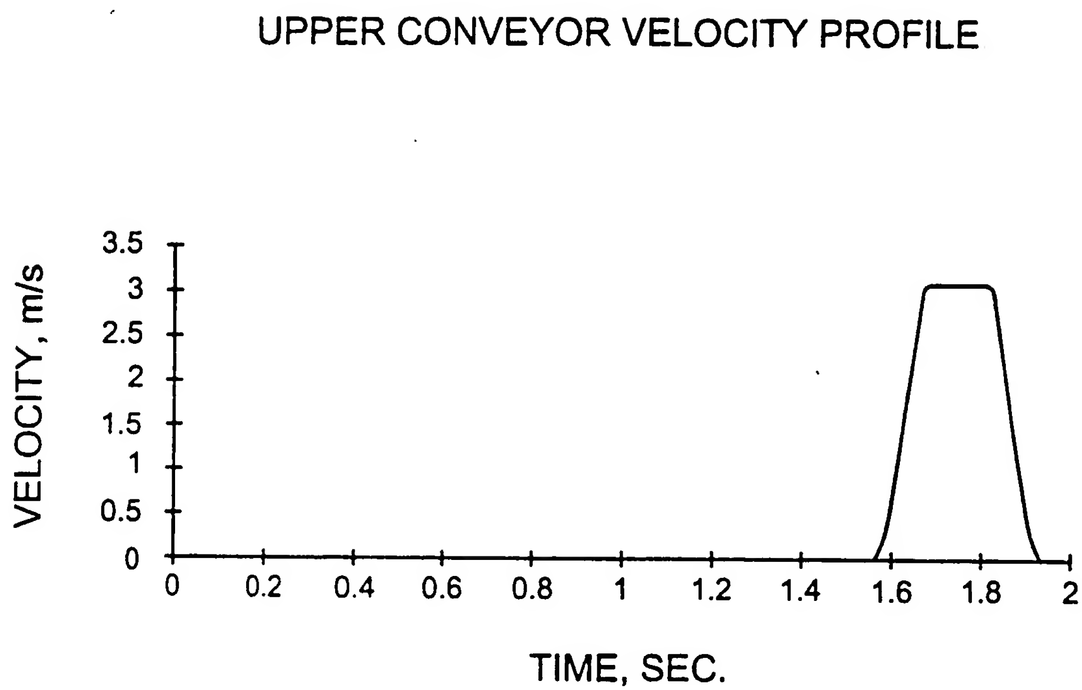

UPPER CONVEYOR VELOCITY PROFILE
VELOCITY, m/s
3.5
3
2.5
2
1.5
1
0.5
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
TIME, SEC.

FIG. 13

UPPER CONVEYOR ACCELERATION PROFILE

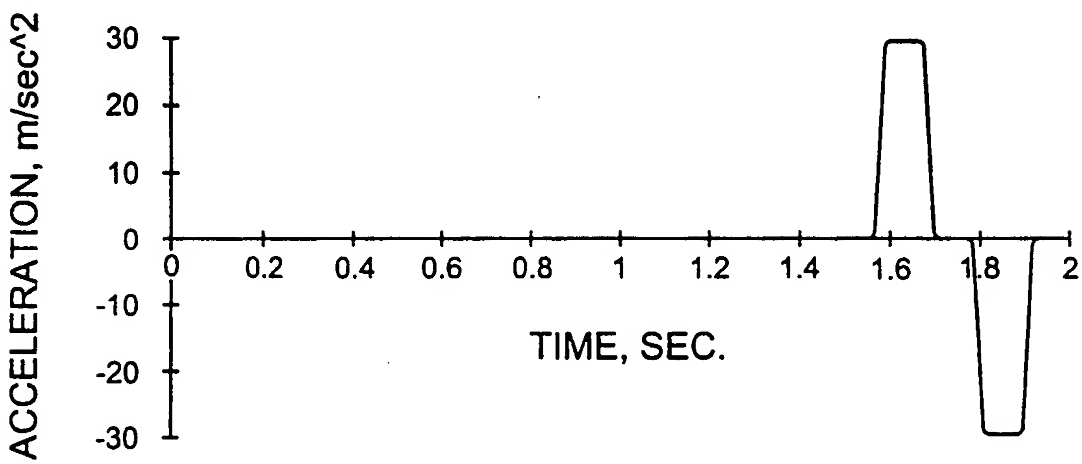


FIG. 14

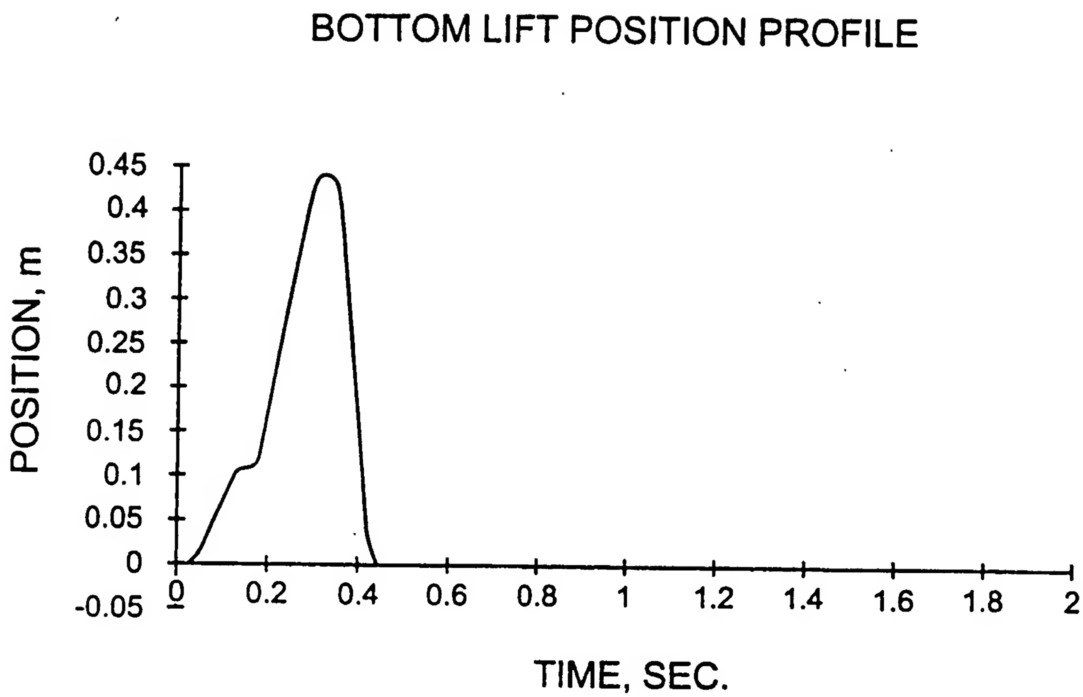

BOTTOM LIFT POSITION PROFILE
POSITION, m
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
TIME, SEC.

FIG. 15

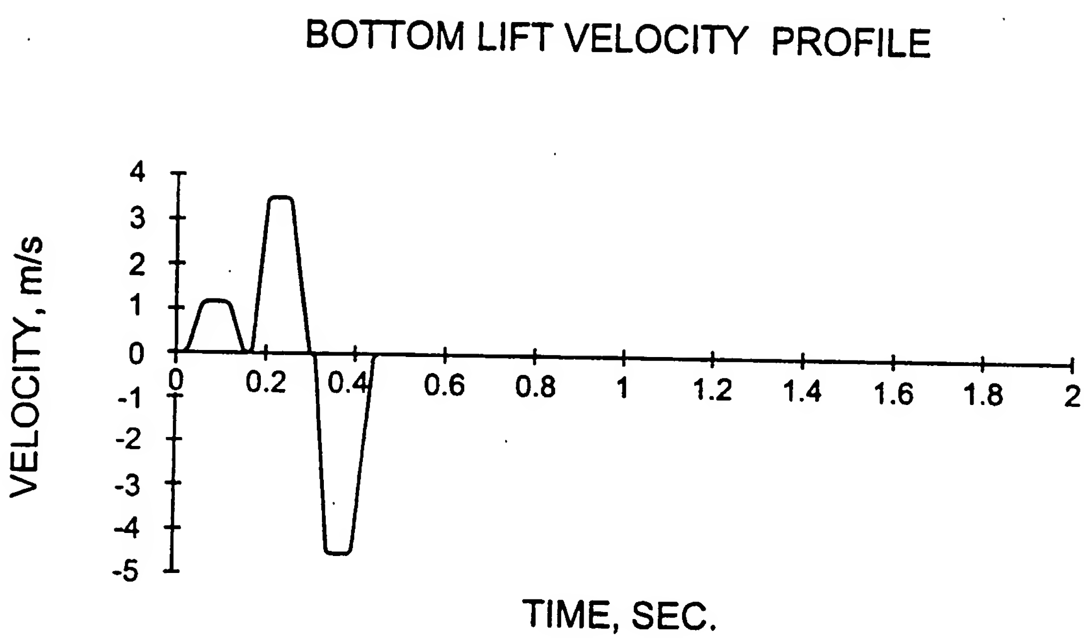

BOTTOM LIFT VELOCITY PROFILE
VELOCITY, m/s
4
3
2
1
0
-1
-2
-3
-4
-5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
TIME, SEC.

FIG. 16

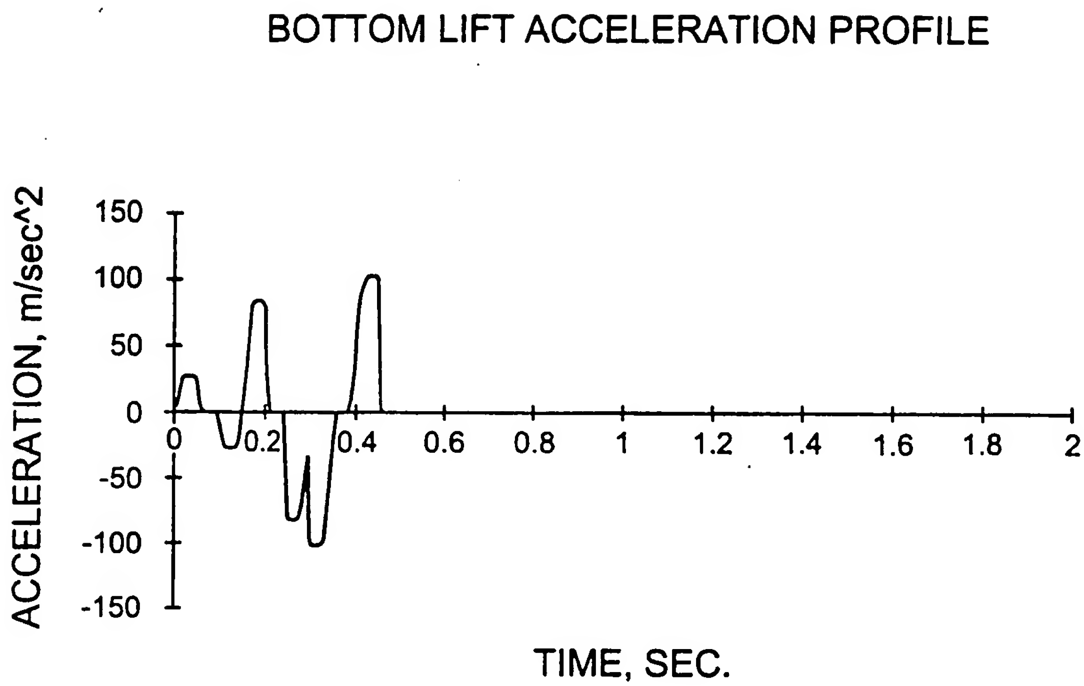

BOTTOM LIFT ACCELERATION PROFILE
ACCELERATION, m/sec^2
150
100
50
0
-50
-100
-150
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
TIME, SEC.

FIG. 17

TOP PREFOLDER POSITION PROFILE

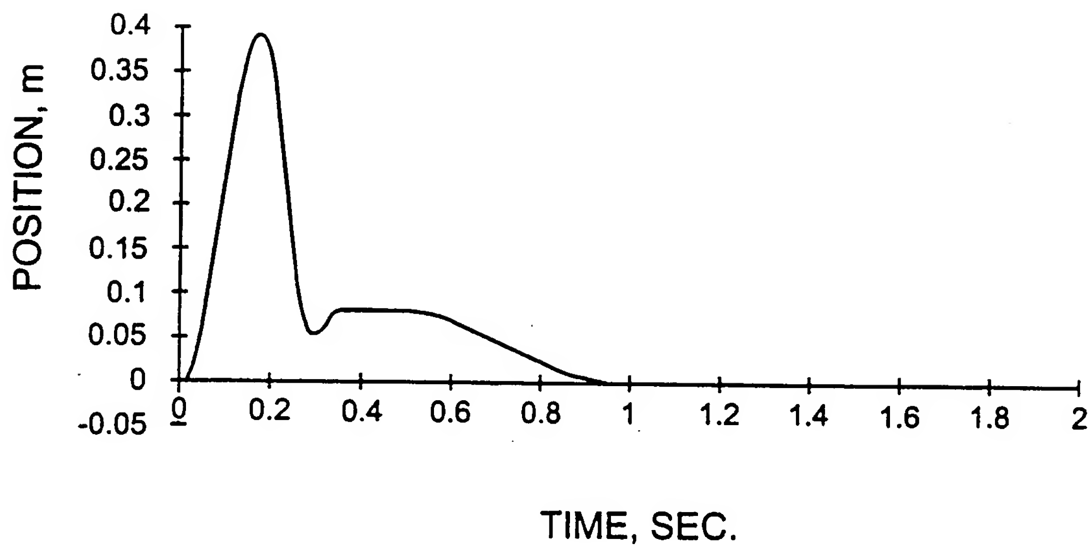


FIG. 18

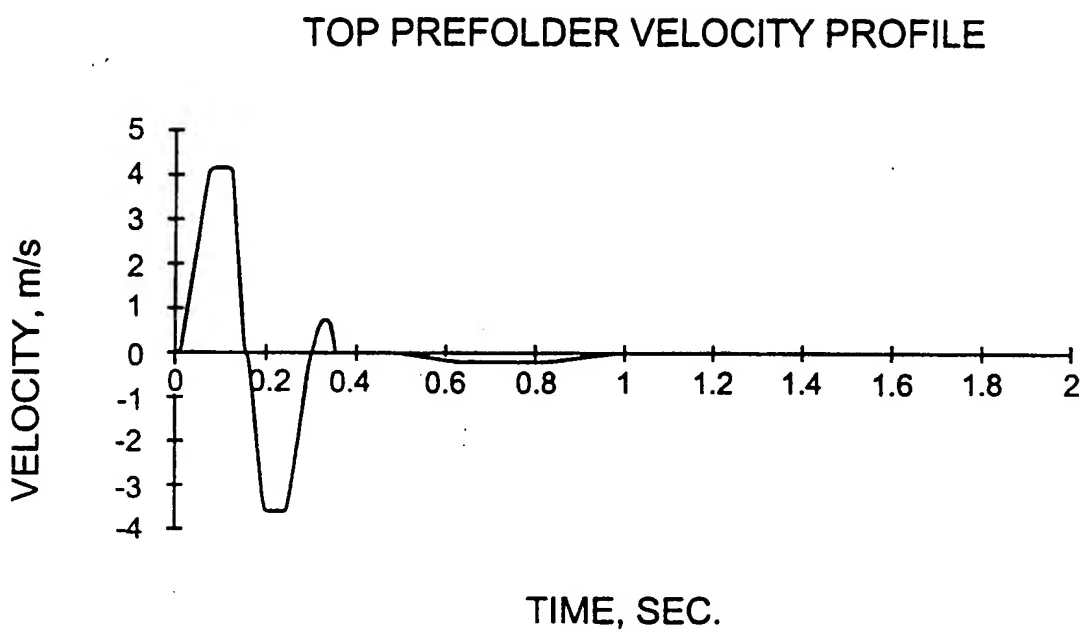

TOP PREFOLDER VELOCITY PROFILE
VELOCITY, m/s
5
4
3
2
1
0
-1
-2
-3
-4
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
TIME, SEC.

FIG. 19

TOP PREFOLDER ACCELERATION PROFILE

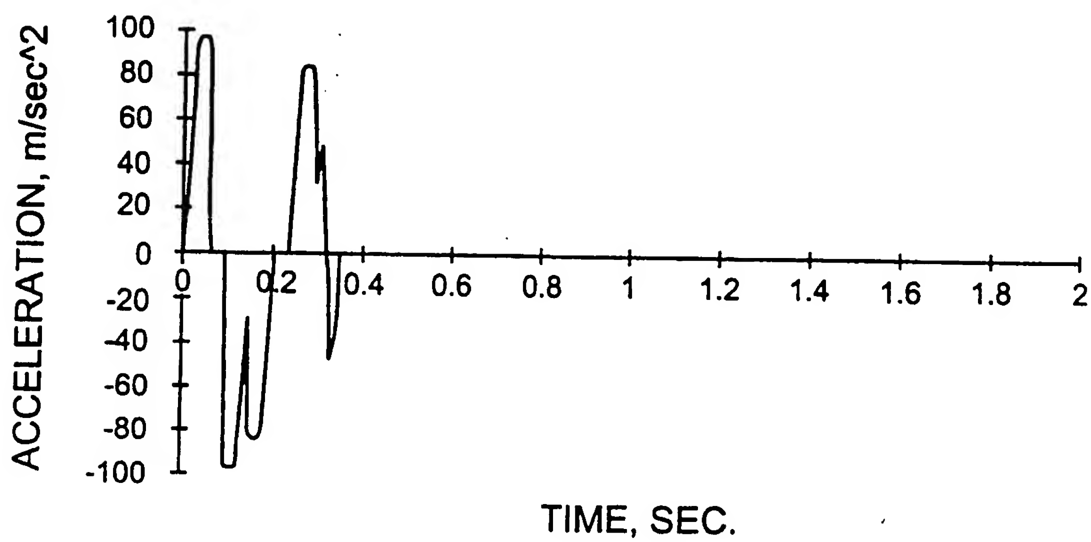


FIG. 20

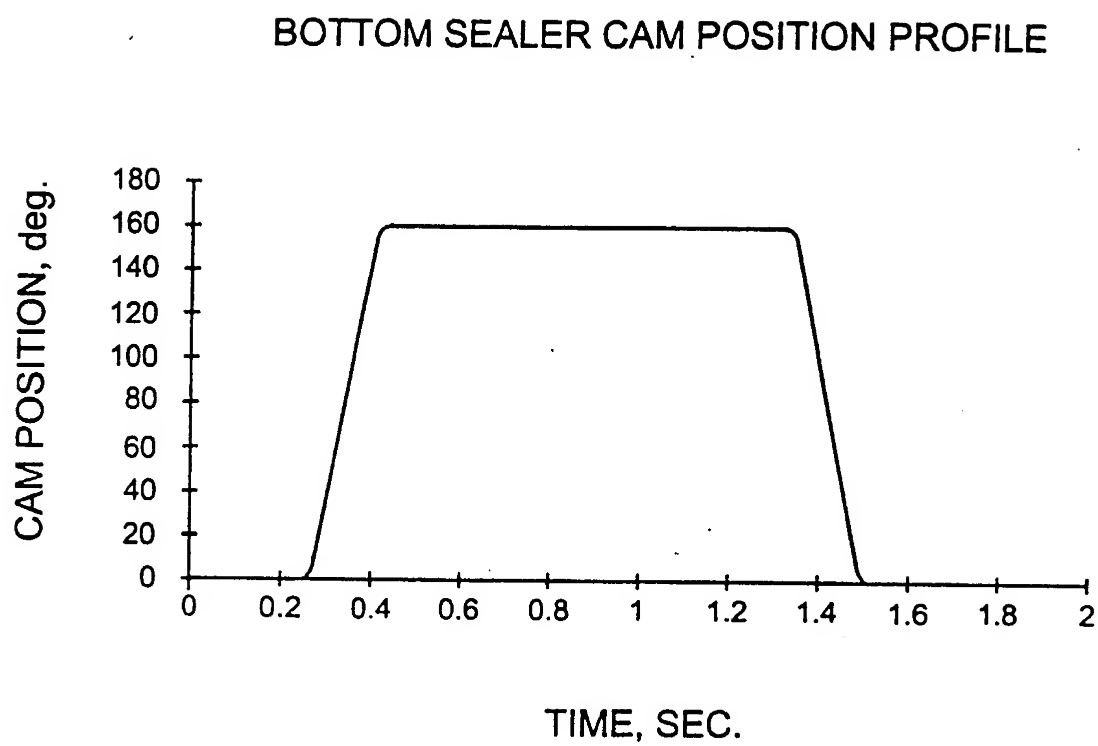

BOTTOM SEALER CAM POSITION PROFILE
CAM POSITION, deg.
180
160
140
120
100
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
TIME, SEC.

FIG. 21

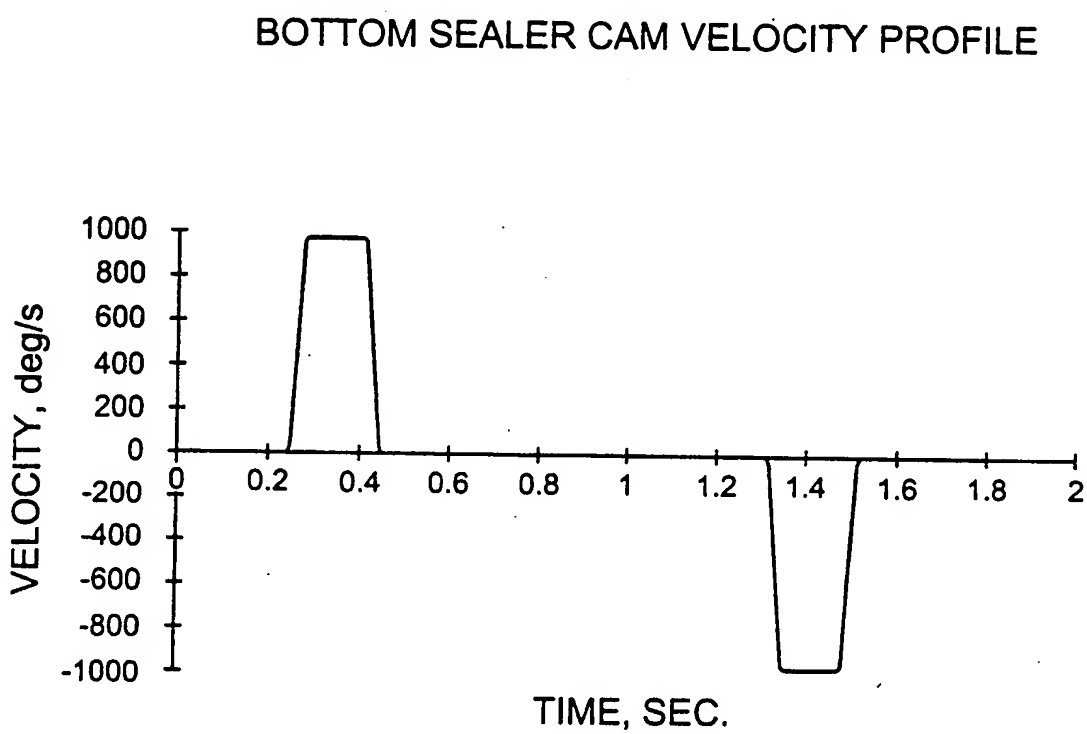

BOTTOM SEALER CAM VELOCITY PROFILE
VELOCITY, deg/s
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
TIME, SEC.

FIG. 22

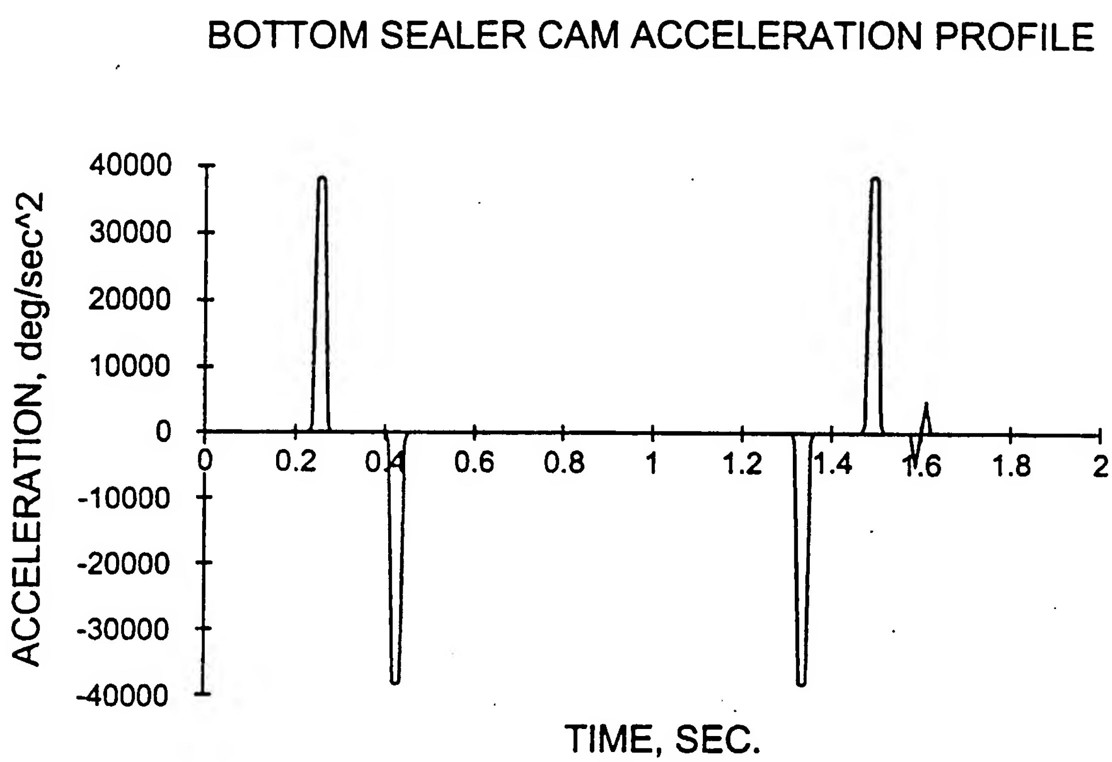

BOTTOM SEALER CAM ACCELERATION PROFILE
ACCELERATION, deg/sec^2
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
TIME, SEC.

FIG. 23

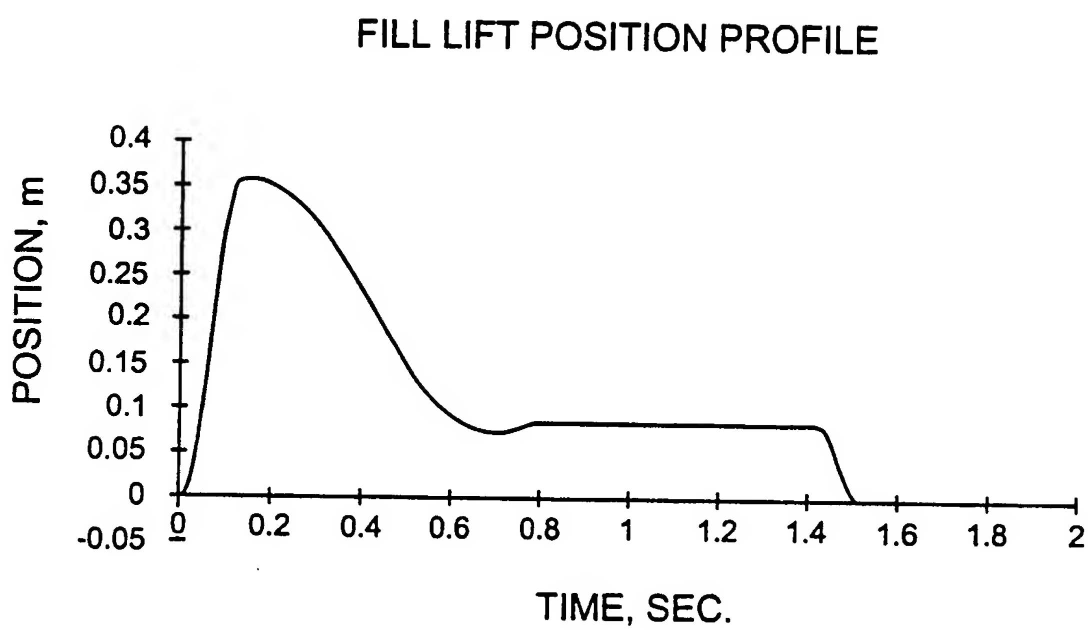

FILL LIFT POSITION PROFILE
POSITION, m
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
TIME, SEC.

FIG. 24

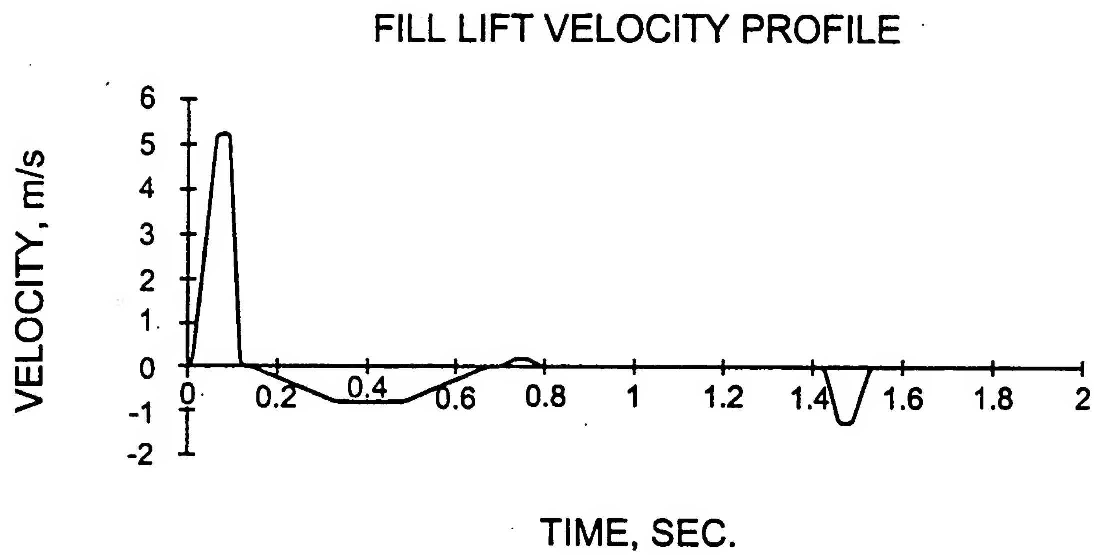

FILL LIFT VELOCITY PROFILE
VELOCITY, m/s
6
5
4
3
2
1
0
-1
-2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
TIME, SEC.

FIG. 25

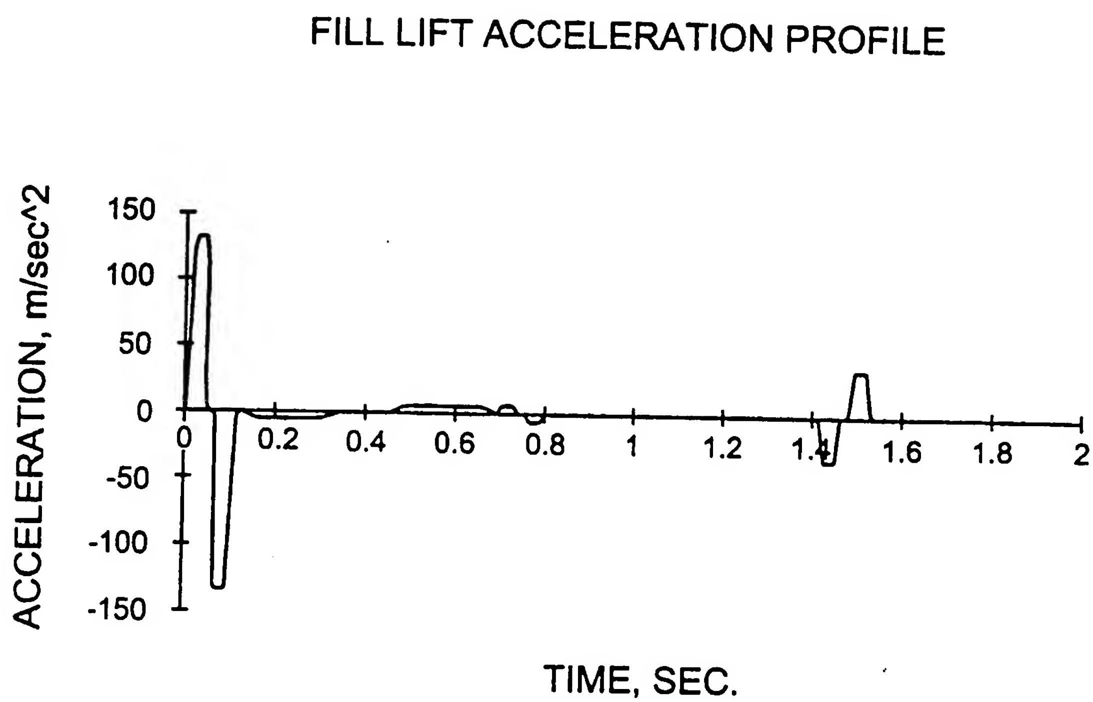

FILL LIFT ACCELERATION PROFILE
ACCELERATION, m/sec^2
150
100
50
0
-50
-100
-150
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
TIME, SEC.

FIG. 26

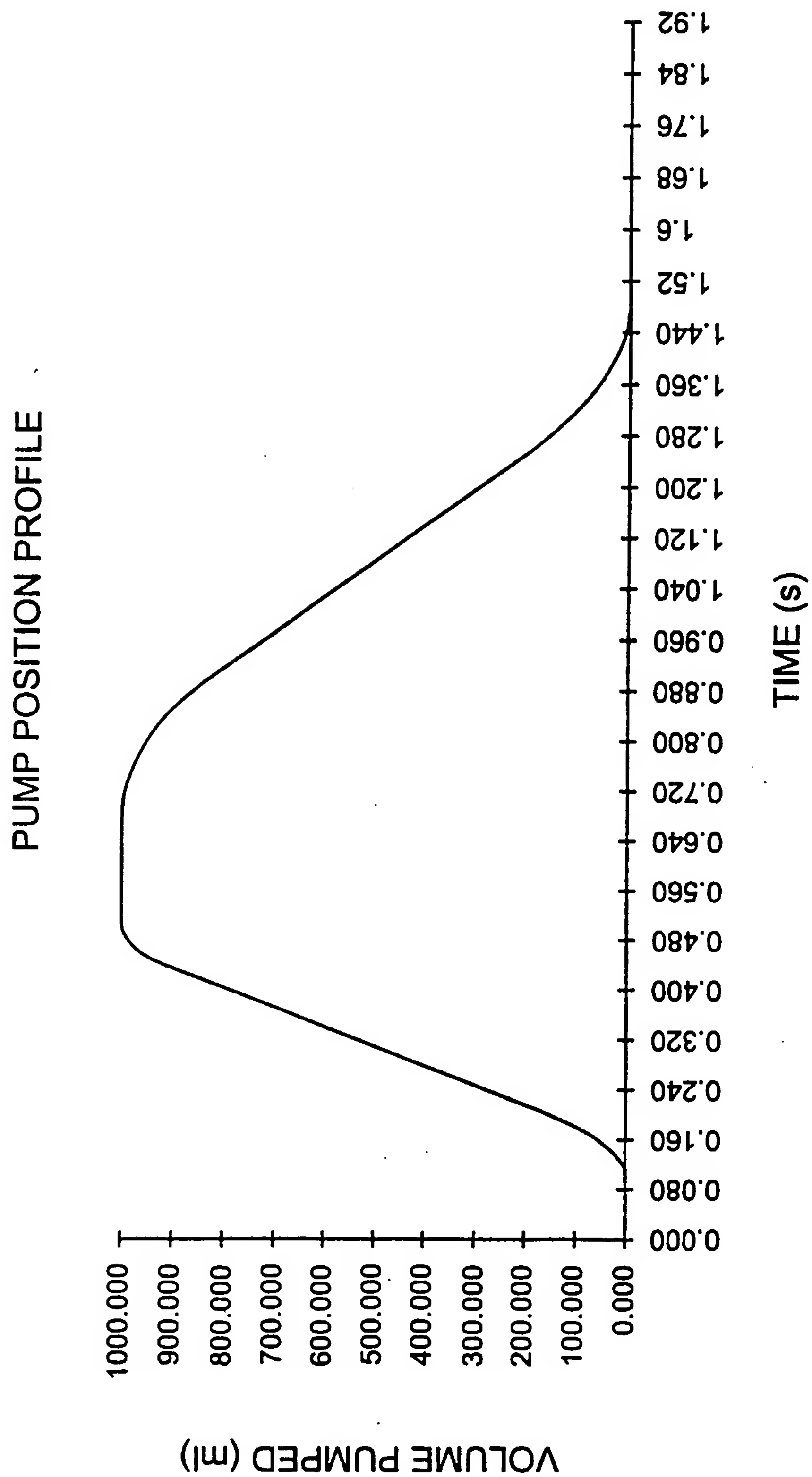

PUMP POSITION PROFILE
VOLUME PUMPED (ml)
0.000
100.000
200.000
300.000
400.000
500.000
600.000
700.000
800.000
900.000
1000.000
TIME (s)
0.000
0.080
0.160
0.240
0.320
0.400
0.480
0.560
0.640
0.720
0.800
0.880
0.960
1.040
1.120
1.200
1.280
1.360
1.440
1.52
1.6
1.68
1.76
1.84
1.92

FIG. 27

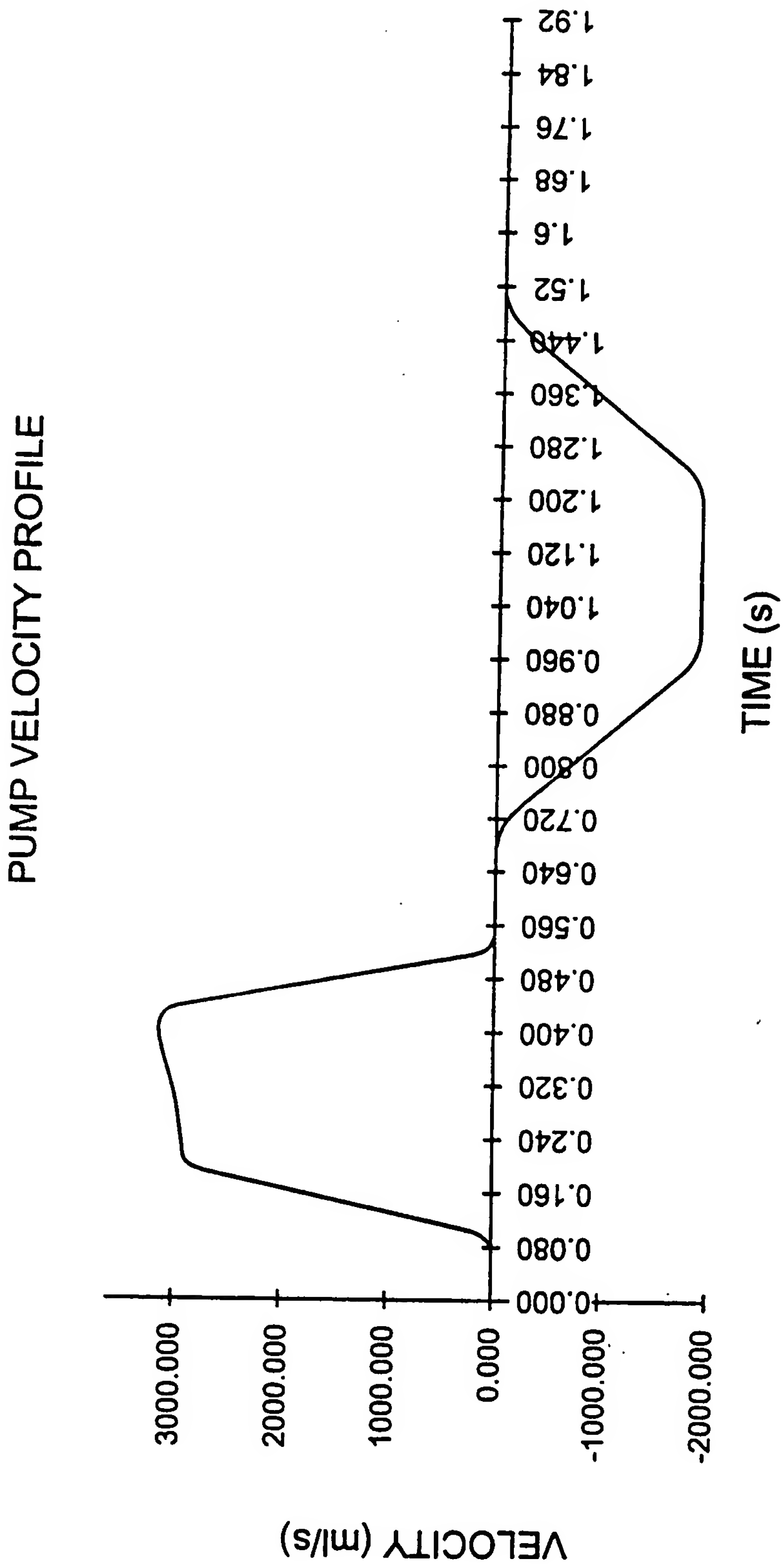

PUMP VELOCITY PROFILE
VELOCITY (ml/s)
TIME (s)
3000.000
2000.000
1000.000
0.000
-1000.000
-2000.000
0.000
0.080
0.160
0.240
0.320
0.400
0.480
0.560
0.640
0.720
0.800
0.880
0.960
1.040
1.120
1.200
1.280
1.360
1.440
1.52
1.6
1.68
1.76
1.84
1.92

FIG. 28

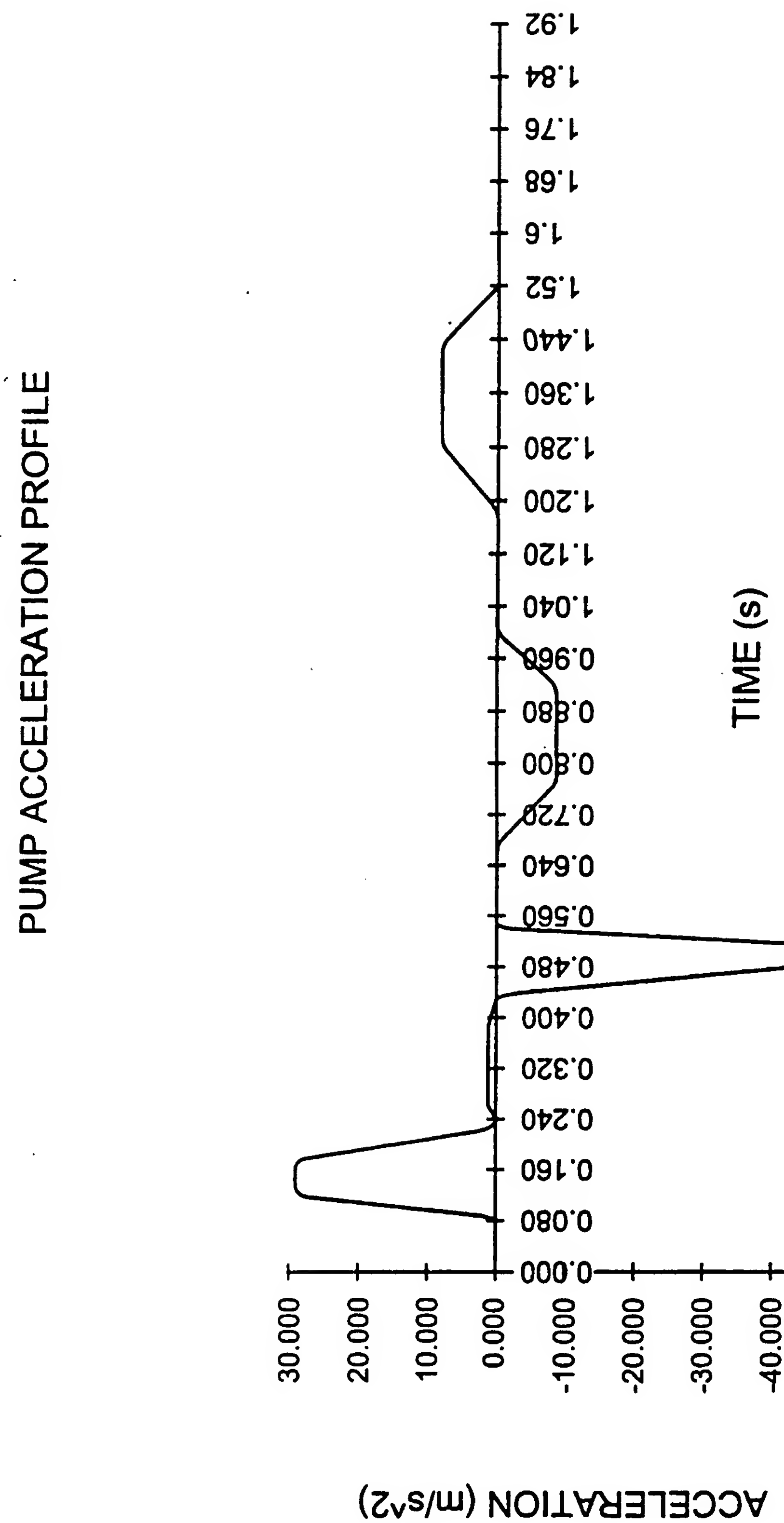

PUMP ACCELERATION PROFILE
ACCELERATION (m/s^2)
30.000
20.000
10.000
0.000
-10.000
-20.000
-30.000
-40.000
-50.000
TIME (s)
0.000
0.080
0.160
0.240
0.320
0.400
0.480
0.560
0.640
0.720
0.800
0.880
0.960
1.040
1.120
1.200
1.280
1.360
1.440
1.52
1.6
1.68
1.76
1.84
1.92

FIG. 29

TOP SEALER CAM POSITION PROFILE

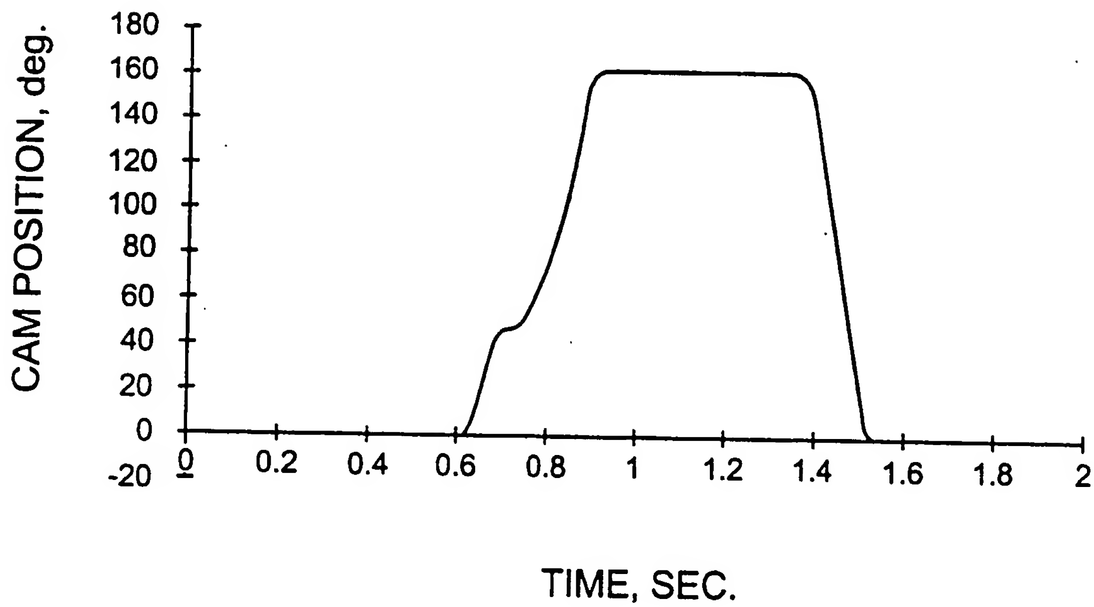
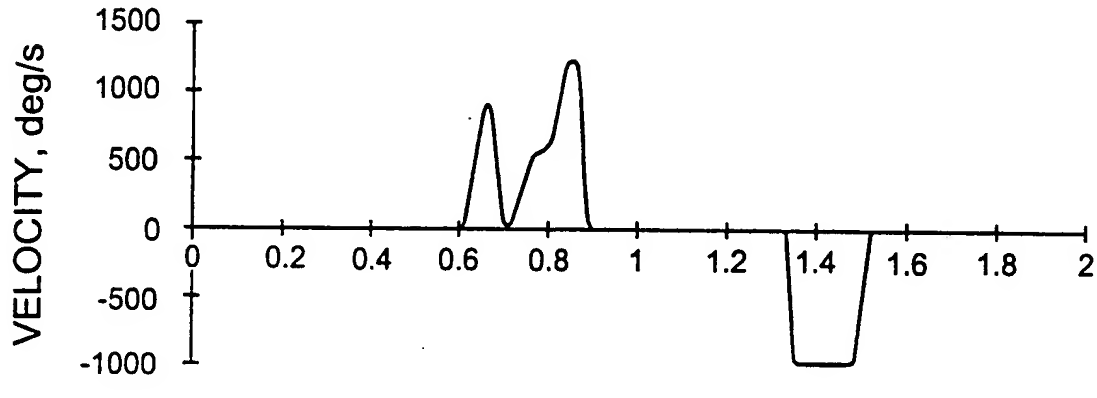


FIG. 30

TOP SEALER CAM VELOCITY PROFILE



TIME, SEC.

FIG. 31

TOP SEALER CAM ACCELERATION PROFILE

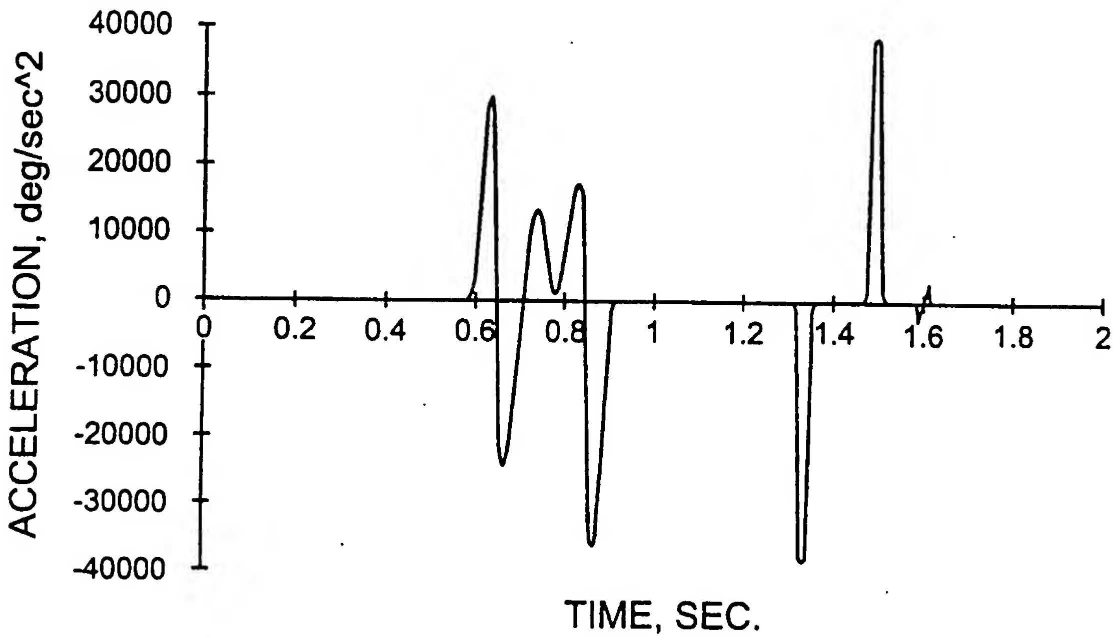


FIG. 32

BOTTOM FORMER LIFT POSITION PROFILE

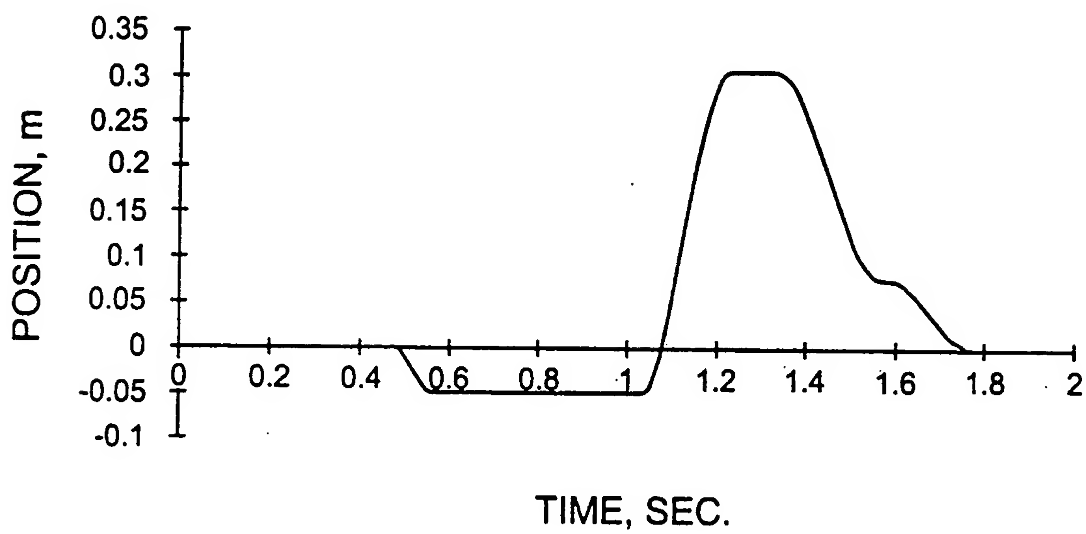


FIG. 33

BOTTOM FORMER LIFT VELOCITY PROFILE

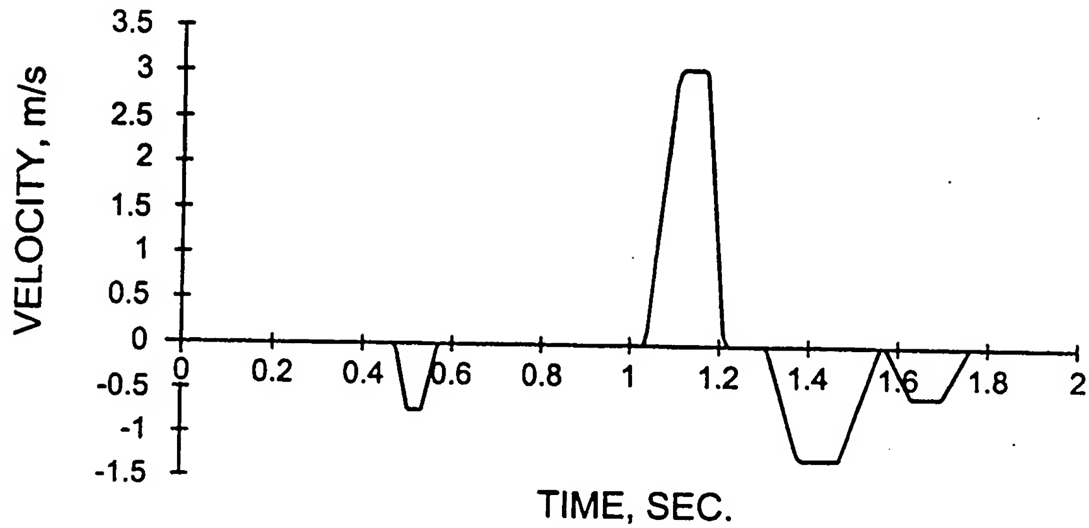


FIG. 34

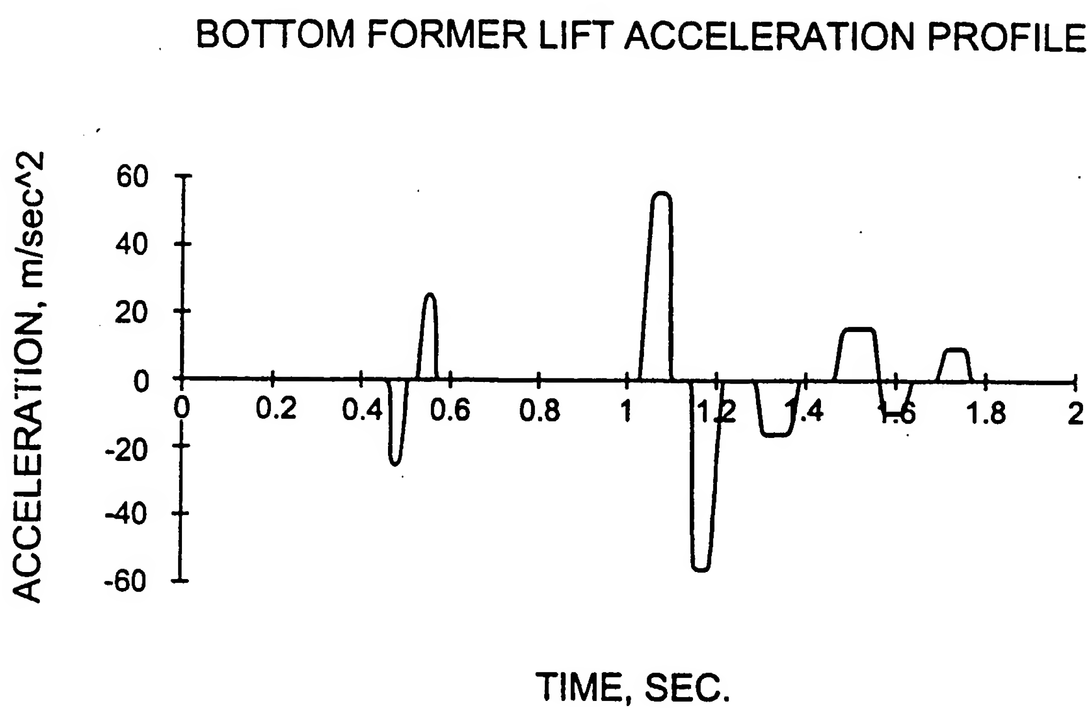

BOTTOM FORMER LIFT ACCELERATION PROFILE
ACCELERATION, m/sec^2
60
40
20
0
-20
-40
-60
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
TIME, SEC.

FIG. 35

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/08793

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B65B 57/00,57/18
US CL : 53/52,508
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 53/52,55,507,508,565

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US, A, 5,551,206 (FUKUDA) 03 SEPTEMBER 1996, COLUMN 3, LINES 24-32; COLUMN 3, LINE 39 TO COLUMN 4, LINE 9; COLUMN 4, LINES 28-37; COLUMN 5, LINES 60-67.	1,7,14,20, 21,24,28, 29,35,36, 39,43 --- 2-6,8-13, 15-19,22, 23,25-27, 30-34,37, 38,40-42
A	US, A, 5,347,791 (GINZL ET AL) 20 SEPTEMBER 1994, FIGURE 6, COLUMN 3, LINE 45-55.	

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 SEPTEMBER 1996	16 SEP 1996

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231
Facsimile No. (703) 305-3230

Authorized officer
for LINDA B. JOHNSON
Sheila Veney
Paralegal Specialist
Group 3200
Telephone No. (703) 308-1148

Form PCT/ISA/210 (second sheet)(July 1992)*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/08793

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 5,146,847 (LYON ET AL) 15 SEPTEMBER 1992, FIGURE 2; COLUMN 3, LINE 55 TO COLUMN 4, LINE 10.	